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Handbook for Preparing User's Guides for Air Quality Models

Aerocomp, Inc., Costa Mesa, CA

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Environmental Sciences Research
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NOTICE

This document has been reviewed in accordance with U.S. Environmental Protection Agency policy and approved for publication. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

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FOREWORD

The Environmental Sciences Research Laboratory conducts a research program in the physical sciences to detect, define, and quantify the effects of air pollution on urban, regional, and global atmospheres. This includes research and development programs designed to quantify the relationships between emissions of pollutants from all types of sources and air quality and atmospheric effects.

The Meteorology and Assessment Division conducts research programs in environmental meteorology to describe the roles and interrelationships of atmospheric processes and airborne pollutants in effective air, and land resource management. Air quality simulation models in the FORTRAN computer language are presently made available through the User's Network for Applied Modeling of Air Pollution (UNAMAP) system.

As the number of models made available has increased, it has become apparent that the user's guide documents describing the dispersion models would be of greater service if they followed a similar style and format. The goal of this document is to provide guidance in the development of high quality dispersion model documentation that is responsive to the requirements of model users.

A. H. Ellison
Director
Environmental Sciences Research Laboratory

ABSTRACT

Suggestions for content, order of material, style, and format are set forth for modelers to follow when writing user's guides for air quality models. A review of coding techniques conducive to model documentation is presented. This material was compiled by the Meteorology and Assessment Division, Environmental Sciences Research Laboratory, U.S. Environmental Protection Agency, to promote consistency among the user's guides.

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SECTION 1

INTRODUCTION

This document has been prepared by the Meteorology and Assessment Division of the U.S. Environmental Protection Agency, to aid in the preparation of user's guides for models and processors. The suggestions presented are in accord with the guidelines set forth by the Office of Research and Development (ORD) for the preparation of ORD scientific and technical reports (U.S. Environmental Protection Agency, 1978). This document addresses the structure and content of dispersion model user's guides, and presents a review of coding techniques designed to assist in documentation.

At present, user's guides are difficult to use and are often confusing, since the content and format vary from document to document. Furthermore, some user's guides suffer from a lack of clarity because extraneous material is presented. Therefore, this handbook suggests:

- what material is considered essential and
- what material is considered useful but not essential,

and recommends:

- the order in which the material is to be presented and
- the manner (i.e., lists, tables, figures) in which the material is to be presented.

These recommendations are based on a review of the currently available UNAMAP user's guides and are not meant to stifle creative writing. Writers, however, are encouraged to stay within documentation standards of the computer industry, which include a complete description of input, output, and processing.

Previous experience with UNAMAP user's guides indicates that the documentation would be more useful if addressed to three main types of individuals: managers, dispersion meteorologists, and computer specialists. Although managers have some familiarity with air quality modeling, they are likely to avoid becoming entangled in the details. Aspects of interest to managers are:

- the types of problems the model will help solve,
- the computing resource requirements, and

- the costs involved.

Dispersion meteorologists, on the other hand, have experience with most of the dispersion modeling techniques, and know the equations for each of the techniques (or at least the limitations to be associated with each technique). In order to assess the applicability of a model to a particular situation, meteorologists need to know the techniques used by the model, the type of input data required to be consistent with the modeling techniques, and the output available.

Computer specialists are interested in the problems that may be encountered while installing and running the model on their computers. They need to know:

- the job flow through the operating system,
- peculiarities and non-standard features of the source code,
- file characteristics, and
- the format and devices used for input and output.

With the above audience in mind, the body of the user's guide may be divided into three parts, the first part directed toward managers, the second, toward dispersion meteorologists, and the third, toward computer specialists. Figure 1, a sample table of contents, shows the sections which may be included in these three parts. Once a user becomes familiar with this format, he can rapidly locate the information needed. Duplication of information is possible with this type of organization; therefore, the writer should endeavor to avoid repetition by writing to the interested audience.

This document also includes a review of coding techniques which will assist the modeler in writing user's guides. It has been shown that orderly code and orderly documentation go hand in hand; maintenance and documentation of poorly written code is not only difficult but costly. On the other hand, properly structured code can be maintained and documented efficiently. Although this presentation of coding techniques is not intended to be exhaustive, it is expected that application of these techniques will result in clearer user's guides and structured dispersion model source code.

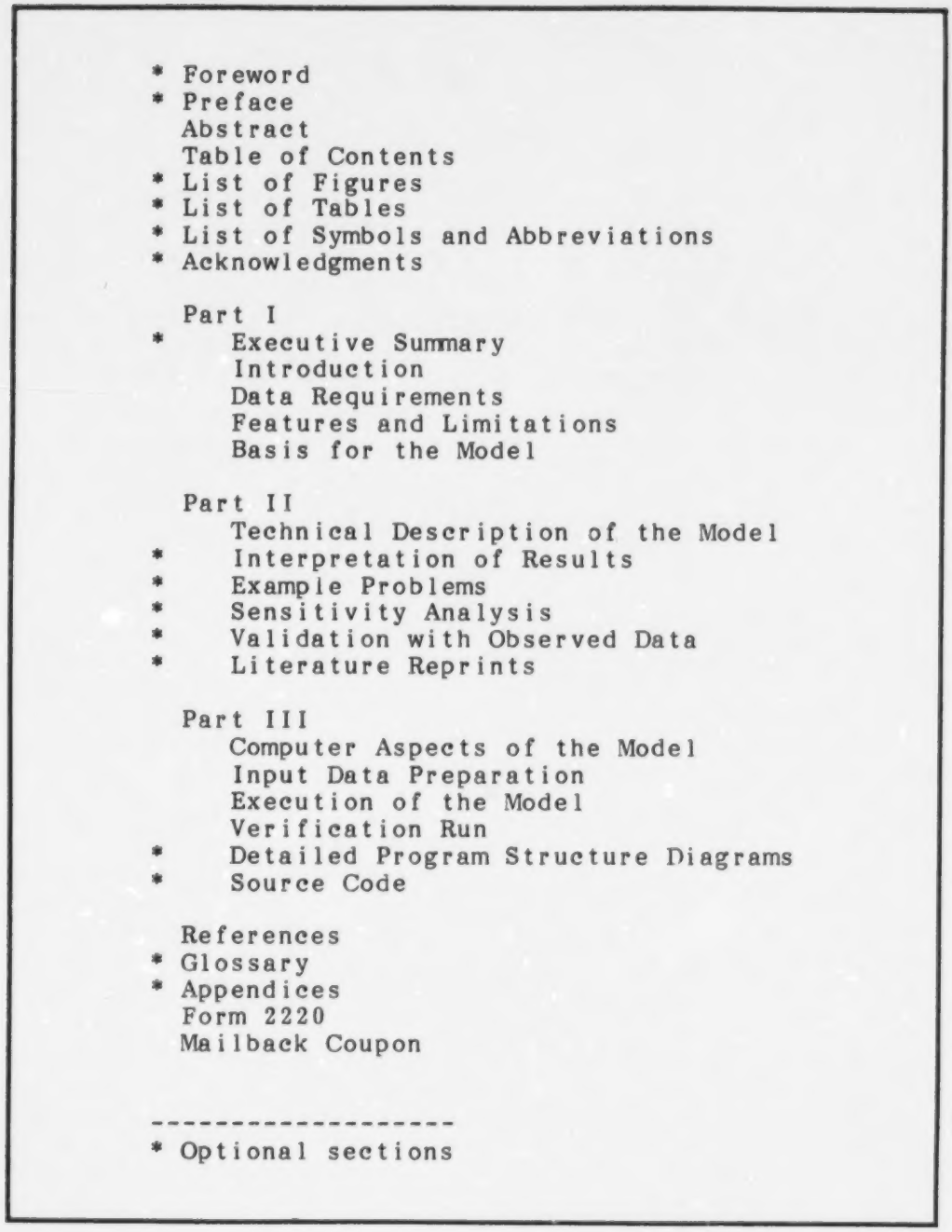

Figure 1. Sample contents of a user's guide.

SECTION 2

CONTENT AND STRUCTURE OF USER'S GUIDES

This section identifies the contents of each section which may appear in a typical user's guide and the order in which the material can be presented. A sample table of contents showing the sections of the user's guide is given in Figure 1.

In addition to conforming to the recommendations presented here, documents should conform to the format specifications given in the EPA report entitled "Handbook for Preparing ORD Reports" (U.S. Environmental Protection Agency, 1982). The third edition of the handbook is in press.

FRONT MATTER

The front matter of the user's guides should provide the reader with information concerning the source of the document, the purpose for which it was written, and an outline of its contents. All front matter should be included in the table of contents. The pages should be numbered with lowercase roman numerals, with the title page of the user's guide as page i; this page, however, should not be numbered.

Foreword

The foreword should be written in non-technical terms and should present to the reader a summary of the background of the model. Included should be information concerning the type and purpose of the model. The foreword should not exceed one page in length. An example is given in Figure 2.

Preface

The preface is intended to provide the reader with any information that he may need before reading the user's guide (e.g., where to direct comments and suggestions). It should also give the reader pertinent information on how the material is organized in the user's guide. It is usually written by the author or developer of the model. A sample preface is given in Figure 3.

Abstract

An abstract should be presented which does not exceed two hundred words in length, describes the document, and identifies the audience. An example is shown in Figure 4.

FOREWORD

Within the Office of Air, Land, and Water Use, the Environmental Sciences Research Laboratory conducts a research program in the physical sciences to detect, define, and quantify the effects of air pollution on urban, regional, and global atmospheres and the subsequent impact on water quality and land use. This includes research and development programs designed to quantitate the relationships between emissions of pollutants from all types of sources and air quality and atmospheric effects.

The Meteorology and Assessment Division conducts research programs in environmental meteorology to describe the roles and interrelationships of atmospheric processes and airborne pollutants in effective air, water, and land resource management. Developed air quality simulation models (in Fortran computer code) are made available to dispersion model users in computer compatible form by availabliity of a magnetic tape from NTIS (See Preface).

RAM is one of the five dispersion algorithms added to UNAMAP in March 1978. RAM is based upon Gaussian dispersion concepts of steady-state modeling. Limitations are imposed on use of the algorithm by the assumptions of non-reactive pollutants and one wind vector and one stability class as representative of the area being modeled. Also computations made under light wind conditions should be interpreted skeptically. In spite of these limitations RAM provides a useful short-term (hours to a day) algorithm for point and area sources for air pollution impact assessment.

L. E. Niemeyer, NOAA
Director, Meteorology and Assessment Division

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Figure 2. Foreword from RAM User's Guide (Turner and Novak, 1978a). Note: Forewords for future user's guides shall have a narrative similar to the Handbook foreword pg, iii, and signed by the laboratory director.

PREFACE

One of the research activities of the Meteorology and Assessment Division focuses on the development, evaluation, validation, and application of air quality simulation, photochemical, and meteorological models capable of describing air quality and atmospheric processes affecting the disposition of airborne pollutants, on scales ranging from local to global. Within the Division, the Environmental Applications Branch adapts and evaluates new and existing meteorological dispersion models and statistical technique models, tailors effective models for recurring user application, and makes these models available through EPA's computer network system.

RAM, an adaptation of Gaussian techniques previously used in point source modeling, uses a rapid executing algorithm for area sources based on the narrow plume hypothesis and has numerous options available to increase user utility. RAM is one of the atmospheric dispersion models on the User's Network for Applied Modeling of Air Pollution (UNAMAP) system. The UNAMAP system may be purchased on magnetic tape from the National Technical Information Service (NTIS) for use on the user's computer system.

Although attempts are made to thoroughly check out computer programs with a wide variety of input data, errors are occasionally found. In case there is a need to correct, revise, or update this model, revisions may be obtained as they are issued by completing and sending the form on the last page of this guide.

Comments and suggestions regarding this publication should be directed to:

Chief, Environmental Applications Branch
Meteorology and Assessment Division (MD-80)
Environmental Protection Agency
RESRCH TRI PK, NC 27711

Technical questions regarding use of the model may be asked by calling (919) 541-4564. Users within the Federal Government may call FTS: 629-4564. Both volumes of the User's Guide are available from NTIS, Springfield, Va. 22161.

The magnetic tape containing all Fortran source codes for RAM, as well as for ten other dispersion models, may be ordered from Computer Products, NTIS. Ask for UNAMAP (Version 3), PB 277 193.

Figure 3. Preface from RAM User's Guide (Turner and Novak, 1978a).

ABSTRACT

The Climatological Dispersion Model (CDM) determines long-term (seasonal or annual) quasi-stable pollutant concentrations at any ground-level receptor using average emission rates from point and area sources and a joint frequency distribution of wind direction, wind speed, and stability for the same period.

This model differs from the Air Quality Display Model (AQDM) primarily in the way in which concentrations are determined from area sources and in the use in the CDM of Briggs' plume rise formula and an assumed power law increase in wind speed with height that depends on stability.

The material presented is directed toward the engineer familiar with computer techniques and will enable him to perform calculations with the CDM. Technical details of the computer programming are discussed; complete descriptions of input, output, and a test case are given. Flow diagrams and a source program listing are included. Companion papers by Calder (1971) on the technical details of the model and by Turner et al. (1972) on validation are included.

Figure 4. Abstract from CDM User's Guide (Busse and Zimmerman, 1973).

Table of Contents

The table of contents should present an indexed outline of the contents of the user's guide. All section and subsection headings which appear in the text must be included in the table. A sample table of contents is shown in Figure 5, although the form does not reflect all the suggestions of this manual.

Lists of Figures and Tables

A list of figures should be included only if helpful or essential. For instance, if particular figures are referenced in a number of places in the text, a list of figures should be included. A sample list of figures is given in Figure 6.

A list of tables should be included only if helpful or essential. For instance, if particular tables are referenced in a number of places in the text, a list of tables should be included. Figure 7 presents a sample list of tables.

List of Symbols and Abbreviations

Any symbols and abbreviations used in the text, except those which are common and obvious, should be listed along with their corresponding definitions. Figure 8 presents a sample list of symbols and abbreviations.

Acknowledgments

Persons or agencies that assisted in the development of either the model or the user's guide should be acknowledged. It is customary to state the way in which those acknowledged assisted in the development of the model or the document. Figure 9 provides a sample.

PART I - DIRECTED TOWARD MANAGERS

Part I of the document should be written in a clear, simple, and non-technical style. While intended primarily for managers, Part I should be directed to a non-technical audience so that laymen wishing to become familiar with the model may do so.

Executive Summary

This section is designed for the person determining the applicability of the model to his needs. It should be one to three pages in length, and it should give a brief overview of model capabilities, data requirements, special computer requirements, and typical execution costs. A sample executive summary is given in Figure 10.

Introduction

While introducing the model and the user's guide, this section should present the rationale and history behind the formation and use of the model.

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Figure 7. List of tables from MPTER User's Guide (Pierce and Turner, 1980).

ABBREVIATIONS AND SYMBOLS

ABBREVIATIONS

EPA	U.S. Environmental Protection Agency
g	grams
hr	hours
km	kilometers
m	meters
mi	miles
sec	seconds
UNAMAP	Users' Network for Applied Modeling of Air Pollution
veh	vehicles

SYMBOLS

A	end point of line source
a	virtual distance for initial σ_z, km
B	end point of line source
b	virtual distance for initial σ_y, km
$C(p)$	concentration at the perpendicular distance, p, g m^{-3}
c	term to determine θ_p, dependent upon stability, degrees
d	factor to determine θ_p, dependent upon stability, degrees
D	line source length, meters
EF	emission factor, g veh^{-1} mi^{-1}
f	point source dispersion function, m^{-2}
g	factor to determine σ_z (depends upon stability and distance range), meters
H	effective source height, meters
h	exponent to determine σ_z (depends upon stability and distance range), dimensionless
L	mixing height, meters
l	distance from point A to point R,S, meters
p	perpendicular distance of receptor from line source, meters
q_l	emission rate from line source, g m^{-1} sec^{-1}

Figure 8. List of symbols and abbreviations from HIWAY User's Guide (Zimmerman and Thompson, 1975).

ACKNOWLEDGMENTS

The authors appreciate the assistance of Adrian D. Busse for placing RAM into the UNAMAP system, and the helpful discussions with John S. Irwin and K. L. Calder.

We appreciate the suggestions for changes received from the Regional Meteorologists and other contributors in EPA regions. These suggested changes arose from their experience in running provisional versions of RAM.

RAM bears the initials of Robert A. McCormick who directed the meteorology program of the Federal air pollution control effort from June 1958 until the time of his retirement in January 1973. His dedicated leadership, encouragement, advice, and counsel throughout this period are greatly appreciated.

The assistance of Theresa Burton, Caryl Whaley, Lea Prince, Nancy Beasley, Bonnie Kirtz, Carolyn Johnston, Sandy Bryant, Tom Pierce, and especially that of Pamela Hinton and Joan Emory is gratefully acknowledged. We thank Ralph Soller for the use of his slide showing point and area sources for the cover.

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Figure 9. Acknowledgments from RAM User's Guide (Turner and Novak, 1978a).

EXECUTIVE SUMMARY

The MPTER computer code (Multiple Point source model with TERrain adjustments) provides a method to estimate air pollutant concentrations from multiple sources in rural environments, and can make optional adjustments for slight terrain variations.

Although the algorithm is based upon Gaussian modeling assumptions and incorporates the Pasquill-Gifford (P-G) dispersion parameter values, several technical options and various parameter values may also be entered as input. Hence, MPTER may be considered a research tool for exploratory use of various assumptions and parameter values.

* * * * * * * * * * * * * * * * *
* If estimates are to be submitted for review to satisfy regula- *
* tory requirements, certain parameter values and options may be re- *
* required. Under these circumstances, specific applications of MPTER *
* should be discussed with the appropriate regional meteorologist to *
* ensure that the calculations are performed in the most appropriate *
* way. *
* * * * * * * * * * * * * * * * *

MPTER can estimate the resulting concentrations at a maximum of 180 receptors from a maximum of 250 point sources. Gaussian assumptions and techniques are used to perform the estimates hourly, considering each hour as a steady state period. Required input information consists of point source and hourly meteorological data. Periods from one hour to one year may be simulated, with all output controlled by the user through selection of options.

Features of the algorithm include:

- Averaging periods of longer than 1 hour, if selected by user.
- Hourly meteorological data that may be read off punched cards for each hour, or from a tape (or disk) containing a year's data (same data as used for RAM or CRSTER).
- An optional terrain adjustment as a function of stability class.
- Inclusion or omission of stack downwash.
- Inclusion of gradual plume rise, or final rise only.
- Inclusion or omission of buoyancy-induced dispersion of pollutant at the source using the method of Pasquill.
- Input of anemometer height.
- Input of wind profile power law exponents as functions of stability.
- Concentration contributions that are available per hour and/or for the selected averaging period at each receptor from up to 25 sources.
- Concentrations available hourly and/or for the selected averaging period at each receptor.
- Optional output of the following information: average concentration over length of record, plus highest five concentrations for each receptor for four averaging times (1-, 3-, 8-, and 24-hour); and an additional averaging time selected by the user.
- Optional output files for further processing of concentrations that are available per hour and for each averaging period.

Figure 10. Executive summary from MPTER User's Guide (Pierce and Turner, 1980).

An effective technique to accomplish this is to list journal articles describing the model and its use. It may be desirable to reprint an article or portion of an article in Part II. This may be cost-effective if it would be necessary to paraphrase or summarize the article to make the user's guide complete, e.g., a technical description of a model. Be sure that permission to reprint is obtained from the publisher. Presenting such a list in the introduction highlights the discussions providing the reader with a convenient review of the historical development of the model. In order to introduce the user's guide, this section should provide an overview of the contents. A sample introduction is given in Figure 11.

Data Requirements

This section should inform the reader of all input data needed to execute the model. However, particulars on input media, formats, etc., should not be discussed in this section, since the preparation of input data is left to Part III. Typically, the following will be covered: meteorology, emissions, receptors, and any program control data. Units for each variable should be specified along with any special information describing the data, such as the frequency of meteorological data. An example related to meteorological input is provided in Figure 12. A check list of required data can also be given as a means of summarizing data requirements.

Features and Limitations

This section gives a more detailed description of the areas of applicability of the model. Any options provided in the code should be discussed. A table of appropriate uses of the model should be given as well as an outline of model limitations; for example, the model may only be applicable for relatively flat terrain. Figure 13 gives an example of this section.

Basis for the Model

A technical description of the modeling design should be given in simple and clear terms. The primary purpose of this section is to describe in narrative form the methods and techniques of the model. A detailed technical description containing equations and derivations should not be presented here but rather in the section "Technical Description of the Model" in Part II. Examples of what should be covered in this section are: the basis for dispersion (Gaussian-plume, finite difference, or some other method), plume rise methodology used, and consideration of terrain. Figure 14 gives an example of the contents of this section.

PART II - DIRECTED TOWARD DISPERSION METEOROLOGISTS

Part II of the body is directed toward dispersion meteorologists, and it should contain material related to theoretical aspects of the model. Sensitivity and validation should also be discussed here.

It is often the case that the development of proper input data, determination of suitability of a model to a particular application, and proper interpretation of the results are the responsibilities of the dispersion

1. INTRODUCTION

The first two sections of the User's Guide for PAL should be beneficial to those determining the applicability of PAL to their particular need.

PAL is a multisource Gaussian-Plume atmospheric dispersion algorithm for estimating concentrations of non-reactive pollutants. Concentration estimates are based on hourly meteorology, and averages can be computed for averaging times from 1 to 24 hours. Six source types are included in PAL: point, area, two types of line sources, and two types of curved path sources. As many as 30 sources may be included under each source type. PAL is not intended as an urban-wide model but may be applied to estimate the contribution of part of an urban area to the concentration. Portions of urban areas assessed by PAL for impact on air quality are:

- Industrial complexes
- Sports stadiums
- Parking lots
- Shopping areas
- Airports

At the heart of PAL is the Gaussian-Plume point source equation (Gifford, 1960). The equation is used directly in the computations for point, line, and curved path sources, and in a modified form for area sources. The point source algorithm is very similar to the point source models provided

on the UNAMAP tape (Hosler, 1975). A unique feature of PAL is the computational technique for estimating the concentration from area sources. This technique incorporates edge effects and is theoretically more accurate than the methods used in the Climatological Dispersion Model (CDM) (Busse and Zimmerman, 1973) and the Air Quality Display Model (AQDM) (Martin, 1971). The horizontal line source algorithm is similar to the Highway Air Pollution Model (HIWAY) (Zimmerman and Thompson, 1975). Input source types also include two types of curved paths, one of which considers variation of emissions along the path. PAL will also estimate concentrations from a line source which has a variation in emission along the source. This line source may be slanted or elevated relative to the ground. PAL offers considerable flexibility to the user. Any or all of the six source subroutines may be utilized. The user also has the options of employing an hourly variation to emission rates and of allowing the wind speed to change with height. Concentration estimates can be made at up to 30 user specified receptor locations.

The User's Guide includes sections on the features and limitations for use of PAL, the organization of the computer program, a description of input data, and an example problem with computer output. A technical discussion of PAL is presented in Appendix A, and a listing of the source code is available in Appendix B.

Figure 11. Introduction from PAL User's Guide (Petersen, 1978).

1.4.1 Meteorological Data

Meteorological data have an important effect on the simulated transport and dispersion of air pollutants. The data required are:

- STABILITY-WIND SUMMARY
- AMBIENT TEMPERATURE
- AMBIENT PRESSURE
- MIXING HEIGHT
- MEAN SPEEDS OF THE WIND SPEED CLASSES

The stability-wind data are the frequencies of occurrence of six wind speed classes by 16 wind directions and by six stability categories for the area and time period of concern. These data define the transport and the degree of dispersion of the pollutant. The mixing height determines the depth through which the pollutant may be mixed before being totally reflected downward. Temperature is used in computing plume rise. Pressure and temperature are used in the optional conversion of concentrations to standard conditions of pressure and temperature.

Meteorological data may be acquired from the National Climatic Center (NCC) at Asheville, North Carolina. The Center is operated by the National Oceanic and Atmospheric Administration. The user must determine whether the available data are representative of the area and period of concern. The NCC will supply summaries of long-term stability-wind data (STAR data) and set the charges for its services. The six-stability deck (Pasquill-Gifford stabilities A through F) should be

1-7

Figure 12. Data requirements from Valley User's Guide (Burt, 1977).

SECTION 3

FEATURES AND LIMITATIONS

As noted previously, PTPLU is an upgraded version of program PTMAX released in mid-1973 (UNAMAP Version 1). Since then, several larger models have been developed, such as CRSTER (U. S. Environmental Protection Agency, 1977), RAM, and MPTER. Certain features of these more complex models suitable for detailed screening have been transferred to PTPLU. Hence, a number of features not found in PTMAX are now available in PTPLU. These improvements are as follows:

- calculations using wind speeds at anemometer height and wind speeds extrapolated to stack top;
- optional gradual plume rise;
- optional stack downwash;
- optional buoyancy-induced dispersion;
- three modes of operation: batch, interactive with a paper terminal, and interactive with a video display;
- input of anemometer height;
- input of mixing height;
- input of wind-profile exponents;
- calculations for any number of single sources in one run; and
- consideration of momentum-dominated as well as buoyancy-dominated plumes.

PTPLU still retains some of the limitations of PTMAX, however. Among these are the following:

- predetermined wind speeds,
- unsuitability for complex terrain,
- no consideration of building downwash,

- no provision for calculating the effect of multiple point sources,
- no consideration of fumigation, and
- no consideration of pollutant removal or chemical reactions.

The model is most applicable within 10 km of the source. Beyond this distance, the estimates are expected to be less accurate, due to mesoscale influences such as wind direction shear with height and changing meteorological conditions during the time of transport.

As a screening model, PTPLU can be applied to single sources for the following:

- monitoring-network design,
- prevention of significant deterioration,
- new source review,
- fuel-conversion studies,
- control technology evaluation, and
- combustion-source permit applications.

PTPLU is primarily useful in determining the maximum one-hour concentration from a point source and the meteorological conditions associated with the maximum. Maximum concentrations are computed for 49 different combinations of wind speed and stability.

PTPLU can also be used in selecting the distances used as input into the models CRSTER and MPTER for generation of polar coordinate receptor arrays.

Figure 13. Features and limitations from PTPLU User's Guide (Pierce, et al., 1982).

3. THEORETICAL BASIS FOR RAM

The basis for RAM is also discussed in Novak and Turner (1976) which is included in this users guide as the Appendix.

DILUTION BY THE WIND

Emissions from continuous sources are assumed to be stretched along the direction of the wind by the speed of the wind. Thus the stronger the wind, the greater the dilution of the emitted plume. To account for an increase in wind speeds with height from point of measurement to stack top, a power law increase with height is used. The exponent used is a function of stability.

DISPERSION RESULTS IN GAUSSIAN-DISTRIBUTED CROSS SECTIONS

The time-averaged concentration distributions through a dispersed plume resulting from a continuous emission from a point source or an area element are considered to be Gaussian in both the horizontal and vertical directions. Modification of the vertical distribution by eddy reflection at the ground or at a stable layer aloft is allowed. This eddy reflection is accomplished by a "folding back" of the portion of the distribution that would extend beyond the barrier if it were absent. This is equivalent to a virtual image source beneath the ground (or above the stable layer).

STEADY-STATE CONDITIONS

Concentration estimates are made for each simulated hourly period using the mean meteorological conditions for that hour as if a steady-state condition had been achieved. Steady-state Gaussian plume equations are used for point sources, and the integrations of these equations are used for area sources.

CONCENTRATION—— SUM OF INDIVIDUAL CONTRIBUTIONS

The total concentration of a pollutant at a receptor is taken as the sum of the individual concentration estimates from each point and area source

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Figure 14. Basis for model from RAM User's Guide (Turner and Novak, 1978a).

meteorologist. Therefore, the scope of the material presented in Part II should assume that competent expertise is available to apply the model properly to a given situation.

Technical Description of the Model

The information in this section is primarily designed to assist the dispersion meteorologist in understanding the theoretical basis and background of the model. Previous user's guides for UNAMAP models provide several good examples of the level of detail to be presented in this section. Equations, figures, and references should be included as needed. Figure 15 is extracted from MPTER's technical description.

Interpretation of Results

This section should explain any special features of the model output, preferably referring to the unit test example in Part III. Any information that may be of use to the dispersion meteorologist in placing error bounds on the modeling results should be presented. Such error bounds can be included in the information going to the air quality manager or other person using the results as an aid in decision making.

Example Problems

Although a short example problem is provided in Part III for testing the program after it has been installed, an example problem which demonstrates the use of program options may be presented in this section. If the model output is extensive, only a description of outputs may be necessary in lieu of voluminous listings.

The effective presentation of model output is not a simple matter. It has been found that one of the best methods for displaying model output is to present annotated copies of the output. In this way the actual model output and explanations are both shown on one page. An example is given in Figure 16. If the length of the output exceeds fifty pages, selected pages should be presented in the user's guide, and the entire output should be put on microfiche.

Sensitivity Analysis

The sensitivity of model estimates to changes in input parameters should be discussed with the results interpreted. Sensitivity studies may be useful for emphasizing the input variables that have greatest impact on the computations.

Validation Studies

Available studies comparing model estimates with measured data are always in demand and should be included in this optional section whenever available. Figure 17 presents segments of a validation study for the Valley Model.

APPENDIX A

POINT SOURCE COMPUTATIONS

Given an east-north coordinate system (R, S), then the upwind distance, x, and the crosswind distance, y, of a point source from a receptor are given by:

$$x = (S_p - S_r) \cos\theta + (R_p - R_r) \sin\theta \quad \text{(A1)}$$

$$y = (S_p - S_r) \sin\theta - (R_p - R_r) \cos\theta \quad \text{(A2)}$$

where R_p, S_p are the coordinates of the point source; R_r, S_r are the coordinates of the receptor, and θ is the wind direction (the direction from which the wind blows). The units of x and y will be the same as those of the coordinate system R, S. In order to determine plume dispersion parameters, distances must be in kilometers or meters. A conversion may be required to convert x and y above to the appropriate units.

The various forms of the Gaussian equation given below are based upon the coordinate scheme with the origin at the ground, and x upwind from the receptor, y crosswind, and z vertical. The Gaussian equations for continuous releases have four components: 1) concentrations are proportional to emission rate, 2) the released effluent is diluted by the wind passing the point of release, 3) the effluent is spread horizontally resulting in a Gaussian or normal (bell-shaped) crosswind distribution at downwind distances, and 4) the effluent is spread vertically. This latter component also results in a normal vertical distribution near the source, which at greater downwind distances is modified by eddy reflection at the ground and, if appropriate, by eddy reflection at the mixing height. Equations A3, A4 and A5 are broken into these four components (see below).

The following symbols are defined:

χ_p, concentration, g m^{-3}

Q, emission rate, g s^{-1}

u, wind speed, m s^{-1}

σ_y, standard deviation of plume concentration horizontal distribution (evaluated at the distance x and for appropriate stability), m

σ_z, standard deviation of plume concentration vertical distribution (evaluated at the distance x and for appropriate stability), m

L, mixing height, m

H, effective height of emission, m

z, receptor height above ground, m

y, crosswind distance, m

The contribution to the concentration, χ_p, from a single point source to a receptor is given by one of the three following equations where the expressions g_1, g_2, g_3, are defined below.

Component: (1) (2) (3) (4)

$$\chi_p = Q \cdot \frac{1}{u} \cdot \frac{g_1}{\sqrt{2\pi}\,\sigma_y} \cdot \frac{g_2}{\sqrt{2\pi}\,\sigma_z} \quad \text{(A3)}$$

$$\chi_p = Q \cdot \frac{1}{u} \cdot \frac{g_1}{\sqrt{2\pi}\,\sigma_y} \cdot \frac{1}{L} \quad \text{(A4)}$$

$$\chi_p = Q \cdot \frac{1}{u} \cdot \frac{g_1}{\sqrt{2\pi}\,\sigma_y} \cdot \frac{g_3}{\sqrt{2\pi}\,\sigma_z} \quad \text{(A5)}$$

For stable conditions or unlimited mixing use equation (A3).

For unstable or neutral conditions, where σ_z is equal to or greater than 1.6 L, use equation (A4).

For unstable or neutral conditions where σ_z is less than 1.6 L, use equation (A5), provided that both H and z are less than L.

Figure 15. Technical description from MPTER User's Guide (Pierce and Turner, 1980).

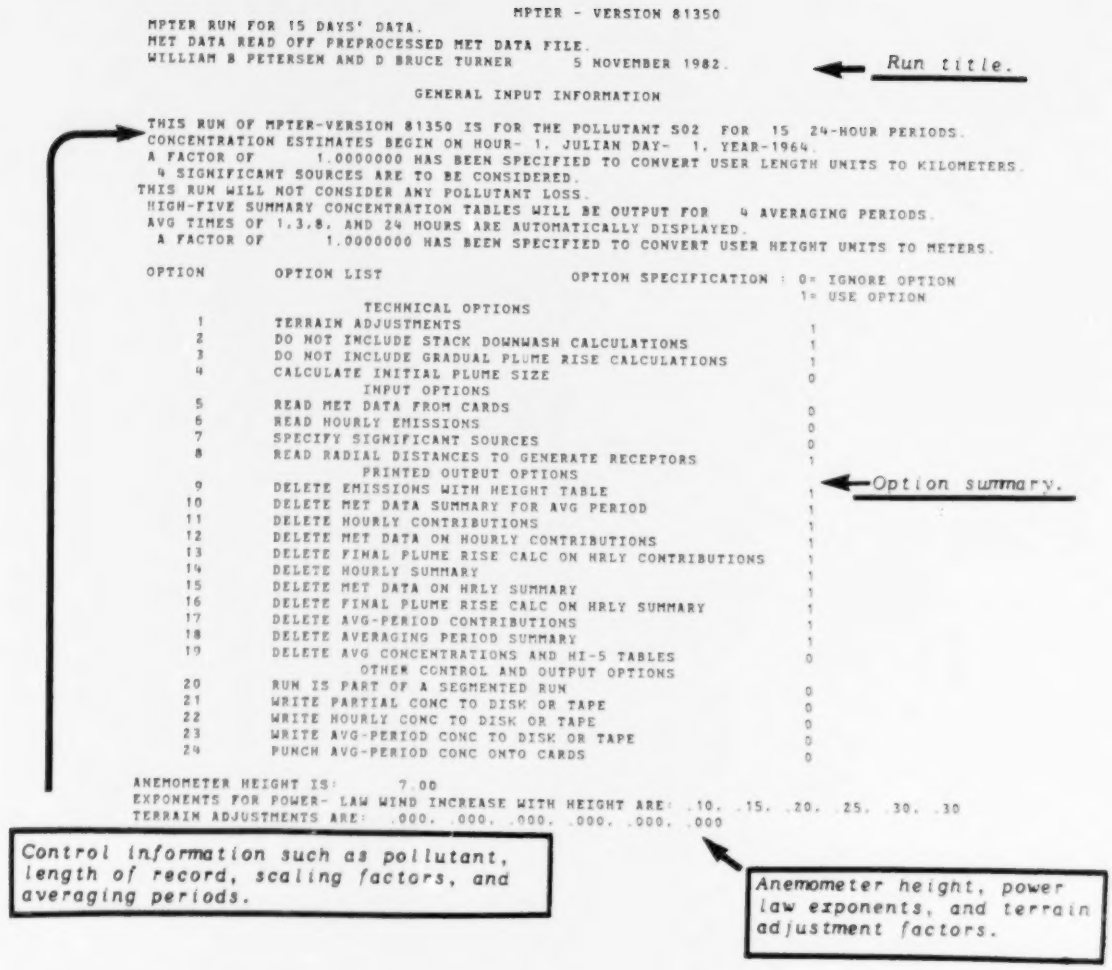
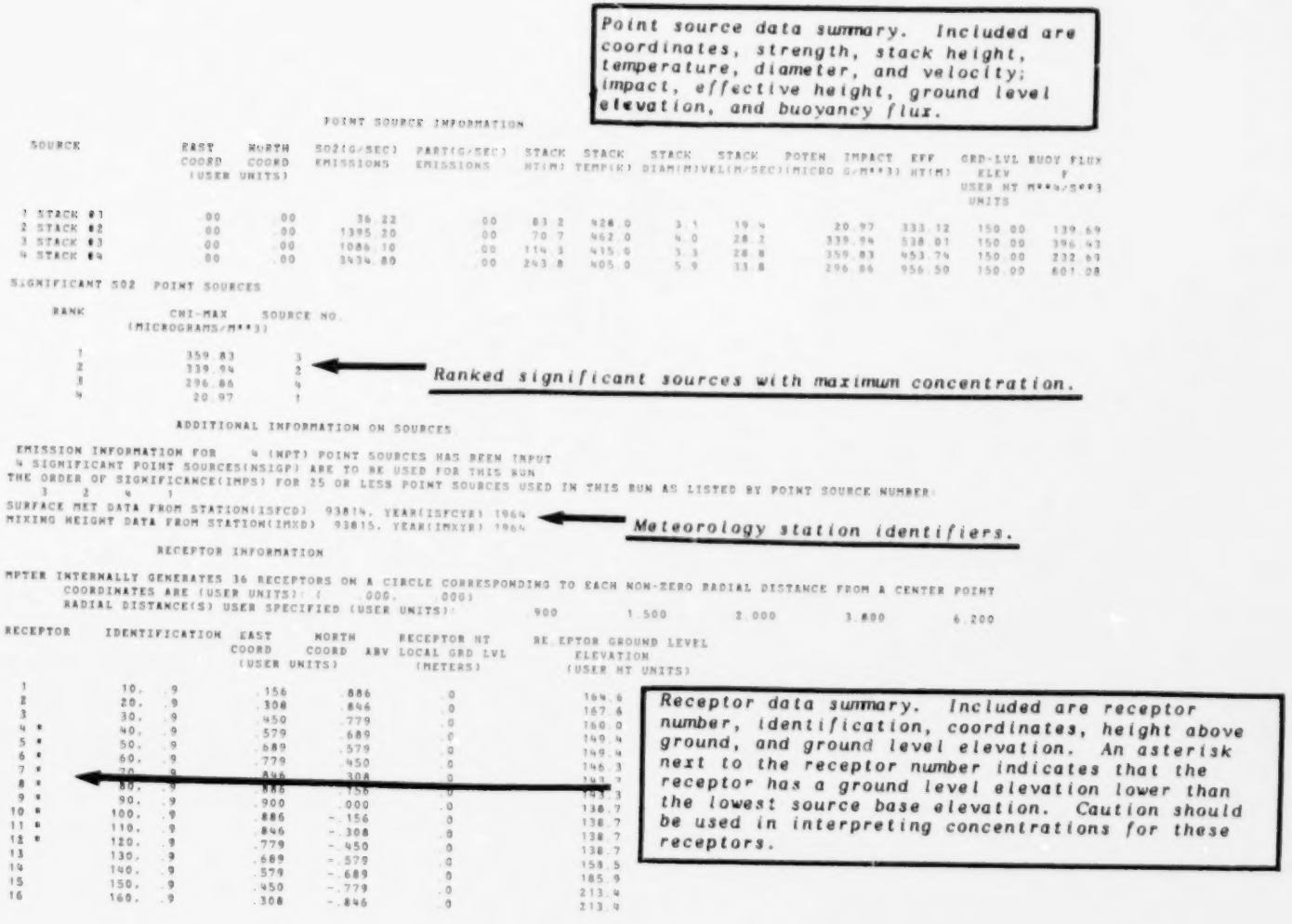

MPTER - VERSION 81350
MPTER RUN FOR 15 DAYS' DATA.
MET DATA READ OFF PREPROCESSED MET DATA FILE.
WILLIAM B PETERSEN AND D BRUCE TURNER 5 NOVEMBER 1982.
Run title.
GENERAL INPUT INFORMATION
THIS RUN OF MPTER-VERSION 81350 IS FOR THE POLLUTANT SO2 FOR 15 24-HOUR PERIODS.
CONCENTRATION ESTIMATES BEGIN ON HOUR- 1, JULIAN DAY- 1, YEAR-1964.
A FACTOR OF 1.0000000 HAS BEEN SPECIFIED TO CONVERT USER LENGTH UNITS TO KILOMETERS.
4 SIGNIFICANT SOURCES ARE TO BE CONSIDERED.
THIS RUN WILL NOT CONSIDER ANY POLLUTANT LOSS.
HIGH-FIVE SUMMARY CONCENTRATION TABLES WILL BE OUTPUT FOR 4 AVERAGING PERIODS.
AVG TIMES OF 1,3,8, AND 24 HOURS ARE AUTOMATICALLY DISPLAYED.
A FACTOR OF 1.0000000 HAS BEEN SPECIFIED TO CONVERT USER HEIGHT UNITS TO METERS.
OPTION OPTION LIST OPTION SPECIFICATION : 0= IGNORE OPTION
1= USE OPTION
TECHNICAL OPTIONS
1 TERRAIN ADJUSTMENTS 1
2 DO NOT INCLUDE STACK DOWNWASH CALCULATIONS 1
3 DO NOT INCLUDE GRADUAL PLUME RISE CALCULATIONS 1
4 CALCULATE INITIAL PLUME SIZE 0
INPUT OPTIONS
5 READ MET DATA FROM CARDS 0
6 READ HOURLY EMISSIONS 0
7 SPECIFY SIGNIFICANT SOURCES 0
8 READ RADIAL DISTANCES TO GENERATE RECEPTORS 1
PRINTED OUTPUT OPTIONS
9 DELETE EMISSIONS WITH HEIGHT TABLE 1
10 DELETE MET DATA SUMMARY FOR AVG PERIOD 1
11 DELETE HOURLY CONTRIBUTIONS 1
12 DELETE MET DATA ON HOURLY CONTRIBUTIONS 1
13 DELETE FINAL PLUME RISE CALC ON HRLY CONTRIBUTIONS 1
14 DELETE HOURLY SUMMARY 1
15 DELETE MET DATA ON HRLY SUMMARY 1
16 DELETE FINAL PLUME RISE CALC ON HRLY SUMMARY 1
17 DELETE AVG-PERIOD CONTRIBUTIONS 1
18 DELETE AVERAGING PERIOD SUMMARY 1
19 DELETE AVG CONCENTRATIONS AND HI-5 TABLES 0
OTHER CONTROL AND OUTPUT OPTIONS
20 RUN IS PART OF A SEGMENTED RUN 0
21 WRITE PARTIAL CONC TO DISK OR TAPE 0
22 WRITE HOURLY CONC TO DISK OR TAPE 0
23 WRITE AVG-PERIOD CONC TO DISK OR TAPE 0
24 PUNCH AVG-PERIOD CONC ONTO CARDS 0
Option summary.
ANEMOMETER HEIGHT IS: 7.00
EXPONENTS FOR POWER- LAW WIND INCREASE WITH HEIGHT ARE: .10, .15, .20, .25, .30, .30
TERRAIN ADJUSTMENTS ARE: .000, .000, .000, .000, .000, .000
Control information such as pollutant, length of record, scaling factors, and averaging periods.
Anemometer height, power law exponents, and terrain adjustment factors.

Figure 16. Sample output from MPTER User's Guide (Pierce and Turner, 1980).



POINT SOURCE INFORMATION

SOURCE		EAST COORD (USER UNITS)	NORTH COORD	SO2(G/SEC) EMISSIONS	PART(G/SEC) EMISSIONS	STACK HT(M)	STACK TEMP(K)	STACK DIAM(M)	STACK VEL(M/SEC)	POTEM (MICRO G/M**3)	IMPACT	EFF HT(M)	GRD-LVL ELEV USER HT UNITS	BUOY FLUX F M***4/S**3
1	STACK #1	.00	.00	36.22	.00	83.2	428.0	3.1	19.4		20.97	333.12	150.00	139.69
2	STACK #2	.00	.00	1395.20	.00	70.7	462.0	4.0	28.2		339.94	538.01	150.00	396.43
3	STACK #3	.00	.00	1086.10	.00	114.3	435.0	3.3	26.8		359.83	453.74	150.00	232.69
4	STACK #4	.00	.00	3434.80	.00	243.8	405.0	5.9	33.8		296.86	956.50	150.00	601.08

SIGNIFICANT SO2 POINT SOURCES

RANK	CNI-MAX (MICROGRAMS/M**3)	SOURCE NO.
1	359.83	3
2	339.94	2
3	296.86	4
4	20.97	1

ADDITIONAL INFORMATION ON SOURCES

EMISSION INFORMATION FOR 4 (NPT) POINT SOURCES HAS BEEN INPUT
4 SIGNIFICANT POINT SOURCES(NSIGP) ARE TO BE USED FOR THIS RUN
THE ORDER OF SIGNIFICANCE(IMPS) FOR 25 OR LESS POINT SOURCES USED IN THIS RUN AS LISTED BY POINT SOURCE NUMBER:
3 2 4 1
SURFACE MET DATA FROM STATION(ISFCD) 93814, YEAR(ISFCYR) 1964
MIXING HEIGHT DATA FROM STATION(IMXD) 93815, YEAR(IMXYR) 1964

RECEPTOR INFORMATION

MPTER INTERNALLY GENERATES 36 RECEPTORS ON A CIRCLE CORRESPONDING TO EACH NON-ZERO RADIAL DISTANCE FROM A CENTER POINT
COORDINATES ARE (USER UNITS): (.000, .000)
RADIAL DISTANCE(S) USER SPECIFIED (USER UNITS): .900 1.500 2.000 3.800 6.200

RECEPTOR	IDENTIFICATION	EAST COORD (USER UNITS)	NORTH COORD	RECEPTOR HT ABV LOCAL GRD LVL (METERS)	RECEPTOR GROUND LEVEL ELEVATION (USER HT UNITS)
1	10. .9	.156	.886	.0	164.6
2	20. .9	.308	.846	.0	167.6
3	30. .9	.450	.779	.0	160.0
4 *	40. .9	.579	.689	.0	149.4
5 *	50. .9	.689	.579	.0	149.4
6 *	60. .9	.779	.450	.0	146.3
7 *	70. .9	.846	.308	.0	143.7
8 *	80. .9	.886	.156	.0	141.3
9 *	90. .9	.900	.000	.0	138.7
10 *	100. .9	.886	-.156	.0	138.7
11 *	110. .9	.846	-.308	.0	138.7
12 *	120. .9	.779	-.450	.0	138.7
13	130. .9	.689	-.579	.0	158.5
14	140. .9	.579	-.689	.0	185.9
15	150. .9	.450	-.779	.0	213.4
16	160. .9	.308	-.846	.0	213.4

Point source data summary. Included are coordinates, strength, stack height, temperature, diameter, and velocity; impact, effective height, ground level elevation, and buoyancy flux.

Ranked significant sources with maximum concentration.

Meteorology station identifiers.

Receptor data summary. Included are receptor number, identification, coordinates, height above ground, and ground level elevation. An asterisk next to the receptor number indicates that the receptor has a ground level elevation lower than the lowest source base elevation. Caution should be used in interpreting concentrations for these receptors.

Figure 16. (continued)

Length of record average concentration ($\mu g/m^3$)

MPTER RUN FOR 15 DAYS' DATA. MPTER - VERSION 81350
MET DATA READ OFF PREPROCESSED MET DATA FILE.
WILLIAM B PETERSEN AND D BRUCE TURNER 5 NOVEMBER 1982.

RECEPTORS

RECEPTOR	IDENTIFICATION	EAST COORD (USER UNITS)	NORTH COORD (USER UNITS)	RECEPTOR HT ABV LOCAL GRD LVL (METERS)	RECEPTOR GROUND LEVEL ELEVATION (USER HT UNITS)	DAY 1.HR 1. TO DAY 15.HR24. AVG CONC FOR PERIOD (MICROGRAMS/M**3)
1	10. .9	.16	.89	.0	164.6	.01
2	20. .9	.31	.85	.0	167.6	.02
3	30. .9	.45	.78	.0	160.0	.01
4	40. .9	.58	.69	.0	149.4	.00
5	50. .9	.69	.58	.0	149.4	.00
6	60. .9	.78	.45	.0	146.3	.00
7	70. .9	.85	.31	.0	143.3	.00
8	80. .9	.89	.16	.0	143.3	.00
9	90. .9	.90	.00	.0	138.7	.00
10	100. .9	.89	-.16	.0	138.7	.00
11	110. .9	.85	-.31	.0	138.7	.00
12	120. .9	.78	-.45	.0	138.7	.00
13	130. .9	.69	-.58	.0	158.5	.00
14	140. .9	.58	-.69	.0	185.9	.00
15	150. .9	.45	-.78	.0	213.4	.00
16	160. .9	.31	-.85	.0	213.4	.00
17	170. .9	.16	-.89	.0	182.9	.09
18	180. .9	.00	-.90	.0	155.4	.01
19	190. .9	-.16	-.89	.0	143.3	.00
20	200. .9	-.31	-.85	.0	138.7	.00
21	210. .9	-.45	-.78	.0	138.7	.00
22	220. .9	-.58	-.69	.0	138.7	.00
23	230. .9	-.69	-.58	.0	138.7	.00
24	240. .9	-.78	-.45	.0	140.2	.00
25	250. .9	-.85	-.31	.0	140.2	.00
26	260. .9	-.89	-.16	.0	143.3	.00
27	270. .9	-.90	.00	.0	146.3	.00
28	280. .9	-.89	.16	.0	152.4	.00
29	290. .9	-.85	.31	.0	161.5	.00
30	300. .9	-.78	.45	.0	185.9	.01
31	310. .9	-.69	.58	.0	219.5	.02
32	320. .9	-.58	.69	.0	205.7	.01
33	330. .9	-.45	.78	.0	192.0	.01
34	340. .9	-.31	.85	.0	179.8	.00
35	350. .9	-.16	.89	.0	170.7	.00
36	360. .9	.00	.90	.0	164.6	.00
					152.4	.00
					167.6	.26
					187.5	1.10
					219.5	2.25
					207.3	20.03
					167.6	2.60
					146.3	.46
					138.7	.08
					138.7	.03
					138.7	.15
					138.7	.04

Receptor data with length of record average concentration. Included in this table are receptor number, receptor identification, height above ground, ground level elevation, and average concentration for the length of record.

Figure 16. (continued)

High-five table. This table presents the five highest concentrations for each receptor for each averaging period. The coordinates of each receptor are printed, and the Julian day and hour during which the concentration occurred. The highest and second-highest concentrations are indicated by an asterisk.

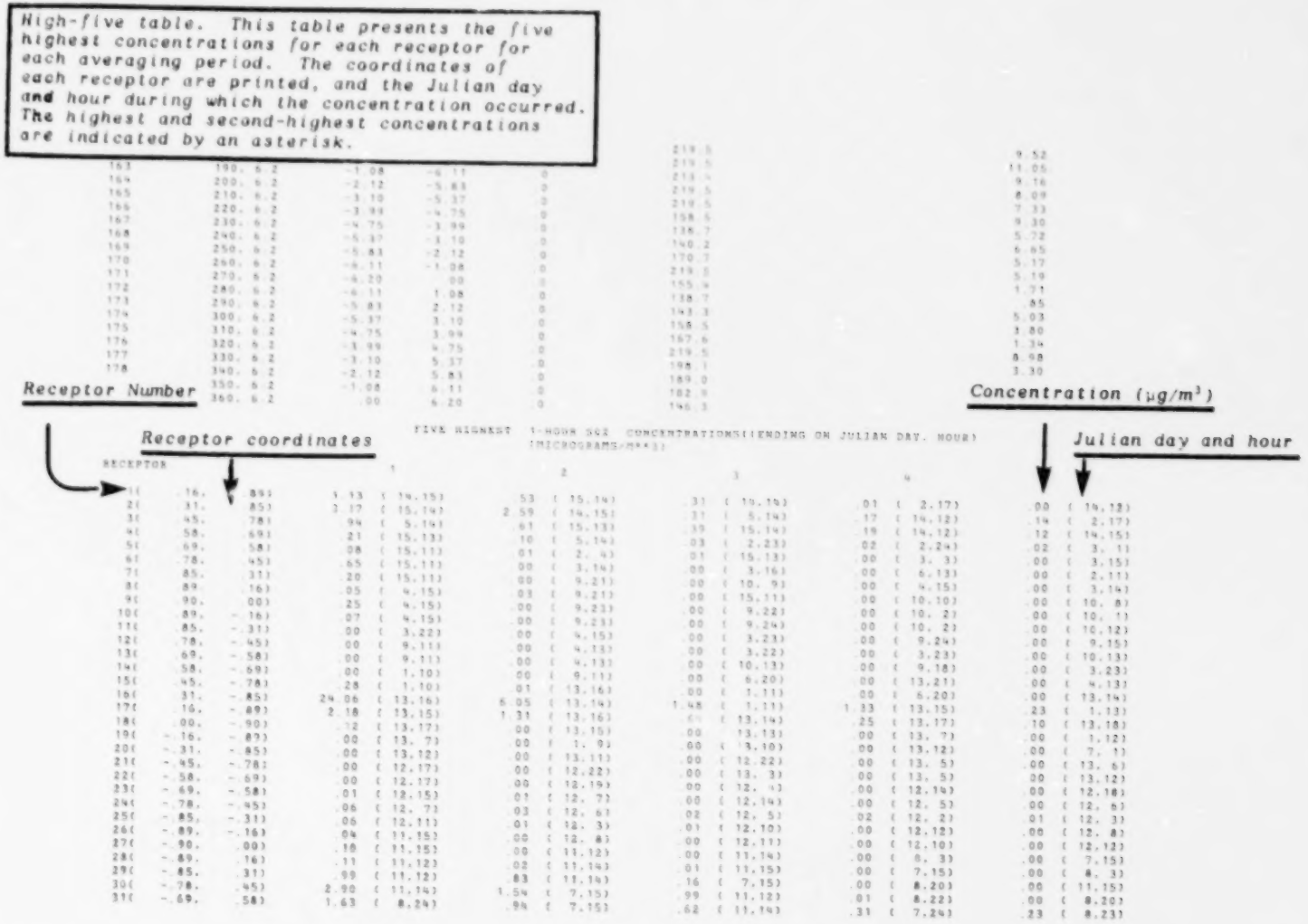
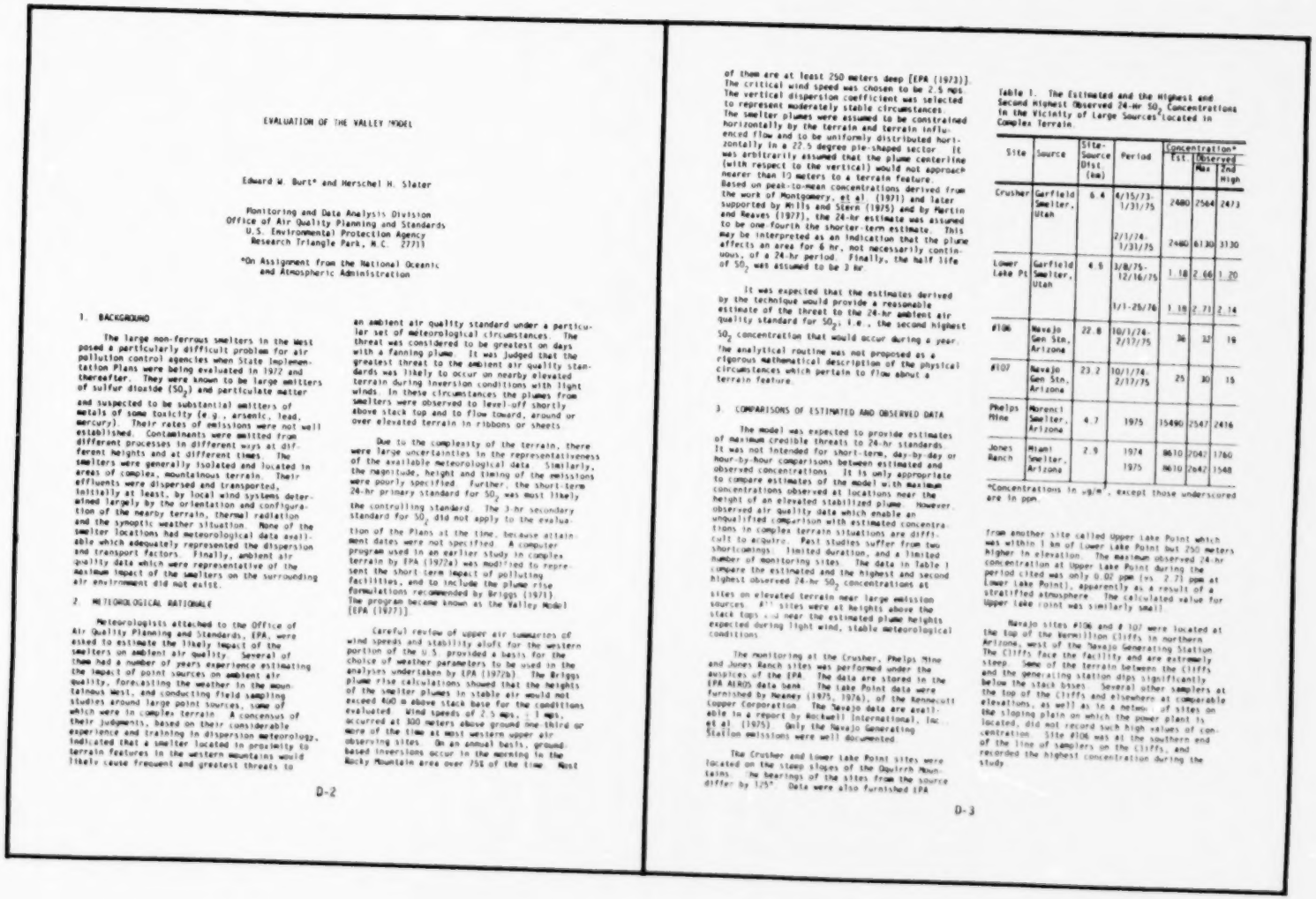


Figure 16. (continued)



EVALUATION OF THE VALLEY MODEL

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1. BACKGROUND

The large non-ferrous smelters in the West posed a particularly difficult problem for air pollution control agencies when State Implementation Plans were being evaluated in 1972 and thereafter. They were known to be large emitters of sulfur dioxide (SO_2) and particulate matter and suspected to be substantial emitters of metals of some toxicity (e.g., arsenic, lead, mercury). Their rates of emissions were not well established. Contaminants were emitted from different processes in different ways at different heights and at different times. The smelters were generally isolated and located in areas of complex, mountainous terrain. Their effluents were dispersed and transported, initially at least, by local wind systems determined largely by the orientation and configuration of the nearby terrain, thermal radiation and the synoptic weather situation. None of the smelter locations had meteorological data available which adequately represented the dispersion and transport factors. Finally, ambient air quality data which were representative of the maximum impact of the smelters on the surrounding air environment did not exist.

2. METEOROLOGICAL RATIONALE

Meteorologists attached to the Office of Air Quality Planning and Standards, EPA, were asked to estimate the likely impact of the smelters on ambient air quality. Several of them had a number of years experience estimating the impact of point sources on ambient air quality, forecasting the weather in the mountainous West, and conducting field sampling studies around large point sources, some of which were in complex terrain. A consensus of their judgments, based on their considerable experience and training in dispersion meteorology, indicated that a smelter located in proximity to terrain features in the western mountains would likely cause frequent and greatest threats to an ambient air quality standard under a particular set of meteorological circumstances. The threat was considered to be greatest on days with a fanning plume. It was judged that the greatest threat to the ambient air quality standards was likely to occur on nearby elevated terrain during inversion conditions with light winds. In these circumstances the plumes from smelters were observed to level-off shortly above stack top and to flow toward, around or over elevated terrain in ribbons or sheets.

Due to the complexity of the terrain, there were large uncertainties in the representativeness of the available meteorological data. Similarly, the magnitude, height and timing of the emissions were poorly specified. Further, the short-term 24-hr primary standard for SO_2 was most likely the controlling standard. The 3-hr secondary standard for SO_2 did not apply to the evaluation of the Plans at the time, because attainment dates were not specified. A computer program used in an earlier study in complex terrain by EPA (1972a) was modified to represent the short term impact of polluting facilities, and to include the plume rise formulations recommended by Briggs (1971). The program became known as the Valley Model [EPA (1977)].

Careful review of upper air summaries of wind speeds and stability aloft for the western portion of the U.S. provided a basis for the choice of weather parameters to be used in the analyses undertaken by EPA (1972b). The Briggs plume rise calculations showed that the heights of the smelter plumes in stable air would not exceed 400 m above stack base for the conditions evaluated. Wind speeds of 2.5 m/s, ± 1 m/s, occurred at 300 meters above ground one-third or more of the time at most western upper air observing sites. On an annual basis, ground based inversions occur in the morning in the Rocky Mountain area over 75% of the time. Most of them are at least 250 meters deep [EPA (1973)]. The critical wind speed was chosen to be 2.5 m/s. The vertical dispersion coefficient was selected to represent moderately stable circumstances. The smelter plumes were assumed to be constrained horizontally by the terrain and terrain influenced flow and to be uniformly distributed horizontally in a 22.5 degree pie-shaped sector. It was arbitrarily assumed that the plume centerline (with respect to the vertical) would not approach nearer than 10 meters to a terrain feature. Based on peak-to-mean concentrations derived from the work of Montgomery, et al. (1971) and later supported by Mills and Stern (1975) and by Martin and Reaves (1977), the 24-hr estimate was assumed to be one-fourth the shorter-term estimate. This may be interpreted as an indication that the plume affects an area for 6 hr, not necessarily continuous, of a 24-hr period. Finally, the half life of SO_2 was assumed to be 3 hr.

It was expected that the estimates derived by the technique would provide a reasonable estimate of the threat to the 24-hr ambient air quality standard for SO_2; i.e., the second highest SO_2 concentration that would occur during a year. The analytical routine was not proposed as a rigorous mathematical description of the physical circumstances which pertain to flow about a terrain feature.

3. COMPARISONS OF ESTIMATED AND OBSERVED DATA

The model was expected to provide estimates of maximum credible threats to 24-hr standards. It was not intended for short-term, day-by-day or hour-by-hour comparisons between estimated and observed concentrations. It is only appropriate to compare estimates of the model with maximum concentrations observed at locations near the height of an elevated stabilized plume. However observed air quality data which enable an unqualified comparison with estimated concentrations in complex terrain situations are difficult to acquire. Past studies suffer from two shortcomings: limited duration, and a limited number of monitoring sites. The data in Table 1 compare the estimated and the highest and second highest observed 24-hr SO_2 concentrations at sites on elevated terrain near large emission sources. All sites were at heights above the stack tops and near the estimated plume heights expected during light wind, stable meteorological conditions.

The monitoring at the Crusher, Phelps Mine and Jones Ranch sites was performed under the auspices of the EPA. The data are stored in the EPA AEROS data bank. The Lake Point data were furnished by Meaney (1975, 1976), of the Kennecott Copper Corporation. The Navajo data are available in a report by Rockwell International, Inc. et al. (1975). Only the Navajo Generating Station emissions were well documented.

The Crusher and Lower Lake Point sites were located on the steep slopes of the Oquirrh Mountains. The bearings of the sites from the source differ by 12°. Data were also furnished EPA from another site called Upper Lake Point which was within 1 km of Lower Lake Point but 250 meters higher in elevation. The maximum observed 24-hr concentration at Upper Lake Point during the period cited was only 0.02 ppm (vs. 2.71 ppm at Lower Lake Point), apparently as a result of a stratified atmosphere. The calculated value for Upper Lake Point was similarly small.

Navajo sites #106 and # 107 were located at the top of the Vermilion Cliffs in northern Arizona, west of the Navajo Generating Station. The Cliffs face the facility and are extremely steep. Some of the terrain between the Cliffs and the generating station dips significantly below the stack bases. Several other samplers at the top of the Cliffs and elsewhere at comparable elevations, as well as to a lesser of sites on the sloping plain on which the power plant is located, did not record such high values of concentration. Site #106 was at the southern end of the line of samplers on the Cliffs, and recorded the highest concentration during the study.

Table 1. The Estimated and the Highest and Second Highest Observed 24-Hr SO_2 Concentrations in the Vicinity of Large Sources Located in Complex Terrain

Site	Source	Site-Source Dist (km)	Period	Concentration* Est.	Observed Max	Observed 2nd High
Crusher	Garfield Smelter, Utah	6.4	6/15/73-1/31/75	2480	2564	2473
			2/1/74-1/31/75	2480	6130	3130
Lower Lake Pt	Garfield Smelter, Utah	4.5	3/8/75-12/16/75	1.18	2.66	1.20
			1/1-25/76	1.18	2.71	2.14
#106	Navajo Gen Stn, Arizona	22.8	10/1/74-2/17/75	36	32	19
#107	Navajo Gen Stn, Arizona	23.2	10/1/74-2/17/75	25	30	15
Phelps Mine	Morenci Smelter, Arizona	4.7	1975	15490	2547	2416
Jones Ranch	Miami Smelter, Arizona	2.9	1974	8610	7042	1760
			1975	8610	7042	1548

*Concentrations in $\mu g/m^3$, except those underscored are in ppm.

Figure 17. Validation study from Valley User's Guide (Burt, 1977).

Results from validation studies may be of considerable use to dispersion meteorologists in assessing the applicability of a model to a particular modeling problem. For instance, a comparison of the quality and representativeness of the input data (both emissions and meteorology) available for a particular modeling problem with the quality of input data used in validation studies may indicate the typical accuracy one might expect for the problem at hand. The importance of interpreting the results of a model in light of the quality and representativeness of the input data is to be stressed.

Values of performance measures that can be abstracted from validation studies might be summarized in tabular form as suggested by Hays (1979). When performance standards are set for various model uses, such tables will be extremely useful for comparing performance measure values against the standards.

Literature Reprints

Journal articles which may be useful to the user and present the rationale and historical development behind the formation and use of the model may be reprinted here. Permission from the publisher to reprint journal articles should be obtained. All reprinted articles should be listed in the table of contents under the section heading.

PART III - DIRECTED TOWARD COMPUTER SPECIALISTS

Part III is directed toward computer specialists and should provide all information needed for proper installation and execution of the model.

Computer Aspects of the Model

This section is addressed primarily to computer specialists and secondarily to dispersion meteorologists. The purpose of this section is to inform the reader of how the model inputs and outputs are controlled and to describe the overall structure of the program. Included in this section should be information concerning any special computer hardware requirements. Warnings should be given of any known problems in installing the code on the various computer systems. If no problems are known, information should be given which could prove useful in determining problems that might arise (e.g., non-standard features employed by the program).

Included in this section should be diagrams and figures that outline the structure of the program; Figure 18 is an example. The input and output flow of the program during execution can be described in a manner similar to that shown in Figure 19. This type of diagram is commonly called a system flowchart, and it describes the input and output media as well as data flow. Again, it should be stressed that this section is meant to familiarize the reader with the overall aspects of the program. The more detailed structure diagrams and the descriptions of the purpose of each of the subroutines are useful, but they are not needed in order to execute the model. Hence, it is preferred that the detailed information be given in a separate optional section called "Detailed Program Structure Diagrams."

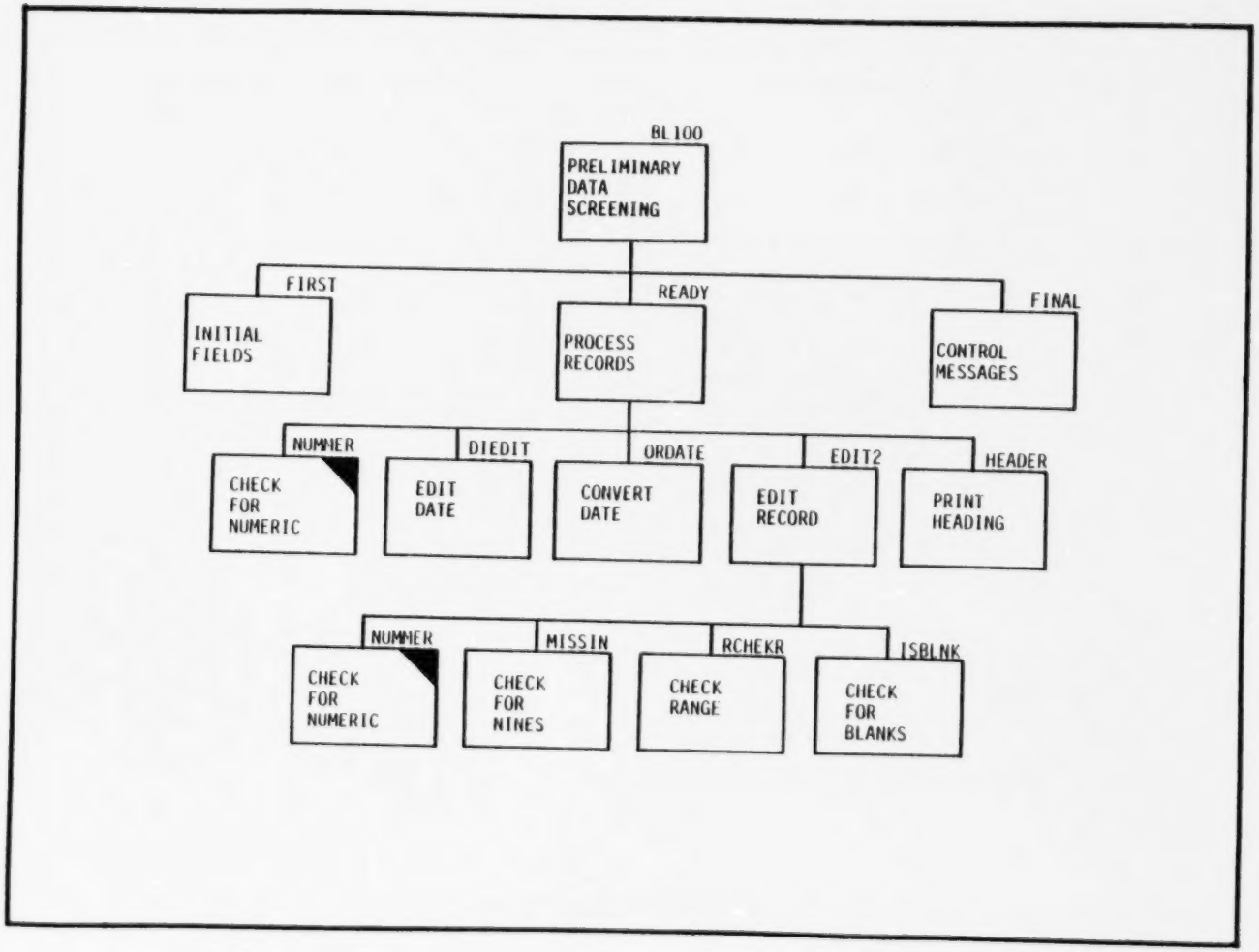

Figure 18. Sample program structure diagram.

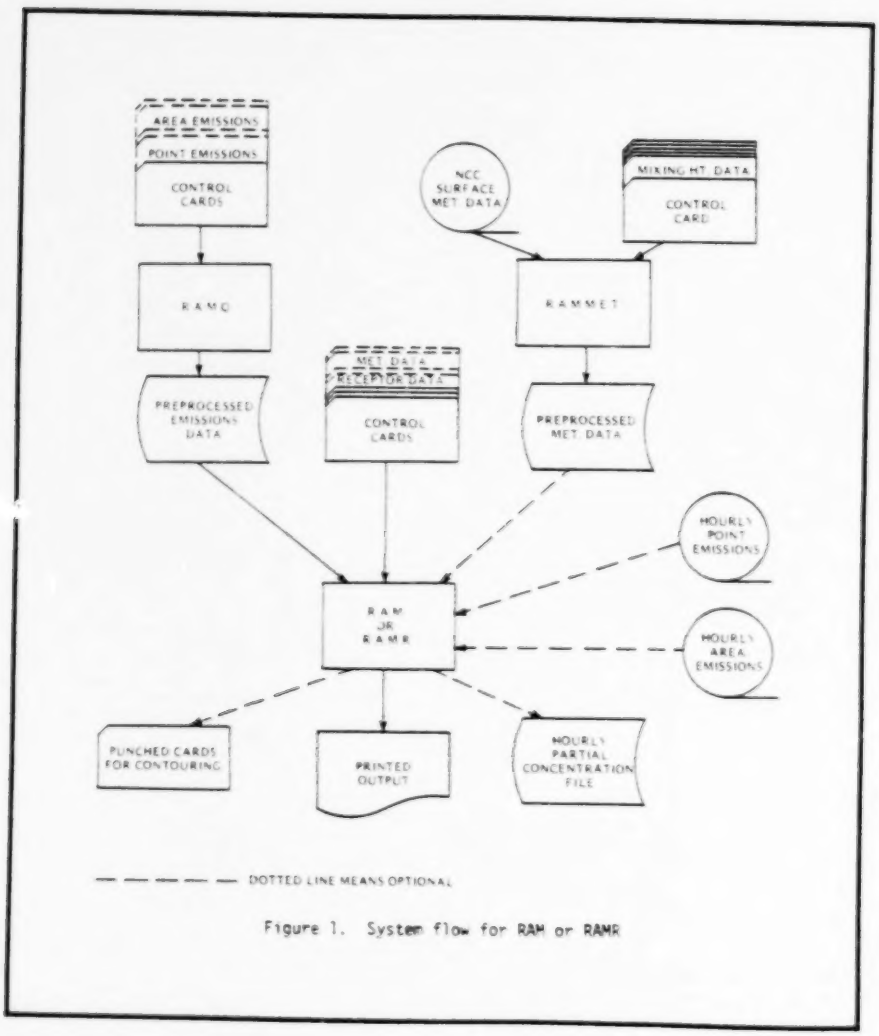

Figure 1. System flow for RAM or RAMR

Figure 19. System chart for RAM (Turner and Novak, 1978b).

Input Data Preparation

Included in this section is information concerning the preparation of the input data. Tables and diagrams describing the data format and units should be used. Special considerations related to input data should be addressed.

It is desirable to standardize the form of the tables and diagrams employed in this section to allow users of UNAMAP models familiarity with the input stream of the various models. There may be no configuration which is flexible enough to describe all possible formats for input data. However, presenting the required inputs in a quasi-standard manner should aid in relating input requirements of different models. One useful technique is illustrated in Figure 20. Narratives describing the intricacies of the input data are also useful, as suggested in Figure 21.

Execution of the Model

Example job run-streams should be provided in this section. One way in which this may be accomplished is shown in Figure 22. Although the actual control language for execution may differ from computer to computer, the computer specialist should be able to translate the control statements included in the section into the appropriate job control language for his computer. A discussion of error messages and pertinent corrective actions is necessary for larger programs; Figure 23 provides an example. A discussion of the processing time, memory requirements, input/output, and costs of executing the model should also be included in this section.

Verification Run

A simple problem should be presented in order to display the input and output of the model and permit the user to verify the execution of the model on his computer by comparing results. It is therefore not necessary to present a real problem; the example should permit verification of the proper execution of most of the code and, at the same time, present a relatively short output showing the main features of the model. The longer examples that demonstrate the use of model options may be presented as a master test in the section "Example Problems" of Part II. The recommendations made in that section of Part II are also applicable here.

Detailed Program Structure Diagrams

Included in this section are functional descriptions of the main program and each subroutine. The descriptions need not be lengthy but should outline the logic and discuss the purpose and methodology. Any detailed flow diagrams required to document the model should be included in this section. Standard flow chart symbols for information processing should be used in any flow diagrams. These symbols are given by the American National Standards Institute (1971). For a fictitious application, Figure 24 illustrates the various symbols available.

Table 6 (continued). CARD INPUT SEQUENCE

Card No.	Column	Format	Contents
	60 to 77	2F9.0	CB(1)-CB(2) (Slope of the linear equation, Y = CA + CB x X, used to calibrate the calculated concentrations of the two pollutants considered in the model)
2	1 to 6	F6.0	DELR (Initial integration increment of radial distance from receptor, meters)
	7 to 12	F6.0	RAT (Ratio of length of a basic emission grid square and the length of a map grid square)
	13 to 18	F6.0	CV (Conversion factor which upon multiplication by RAT expresses the distance of the side of an emission grid square in meters. For example, if the map units are in kilometers, CV=1000.)
	19 to 24	F6.0	HT (Average afternoon mixing height in meters)
	25 to 30	F6.0	HMIN (Average nocturnal mixing height in meters)
	31 to 36	F6.0	XG (X map coordinate of the southwest corner of the emission grid array)
	37 to 42	F6.0	YG (Y map coordinate of the southwest corner of the emission grid array)
	43 to 48	F6.0	XGG (X map coordinate of the southwest corner of the plotting grid)
	49 to 54	F6.0	YGG (Y map coordinate of the southwest corner of the plotting grid)
	55 to 60	F6.0	RATG (Ratio of the length of the grid square used for plotting and the length of a map grid square)
	61 to 66	F6.0	TOA (Mean atmospheric temperature in degrees centigrade)
	67 to 72	F6.0	TXX (Width of basic emission square in meters)
3	1 to 6	F6.0	DINT (Number of intervals used to integrate over a 22.5° sector. Maximum value is 20, typical value is 4.)
	7 to 12	F6.0	YD (Ratio of average daytime emission rate to the 24-hour emission rate average)

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Figure 20. Input data preparation table from CDM User's Guide (Busse and Zimmerman, 1973).

Table 1 should be helpful in organizing data for input into PAL. However, there are several variables that may need further explanation. The balance of this section will be concerned with explaining the use of these input variables and should aid the user in assigning values to them.

POINT SOURCES

In the point source subroutine (POINT) the stack gas velocity (VSP) and stack inside diameter (DP) are ignored if the stack gas volume flow (VFP) is greater than zero. However, VSP and DP must still be specified with dummy values since the free format requires values for all variables. If there are no point sources in a particular run, then the ambient air temperature (WTA) from the meteorology input card type 10 is ignored. If WTA equals zero, then a value of 293^{0}K is assumed in the program.

In subroutine POINT the initial dispersion parameters SYOP and SZOP allow for initial dispersion in the horizontal and vertical, respectively. For a tall stack these parameters would generally have little influence on downwind concentrations. The initial dispersion parameters would be helpful in accounting for the initial mixing of a plume in the building wake. Due to the complex turbulence in the building wake, plume dispersion is best modeled using physical models. However, there are some simple cases where the initial dispersion parameters would be applicable. The values suggested for SYOP and SZOP in this report should be considered preliminary in nature. It is beyond the scope of this report to undertake a detailed discussion of aerodynamic effects in the wake of a building. Some pertinent points are discussed below concerning the circumstances in which aerodynamic effects are a problem and where SYOP and SZOP might be useful.

21

Figure 21. Intricacies of data from PAL User's Guide (Petersen, 1978).

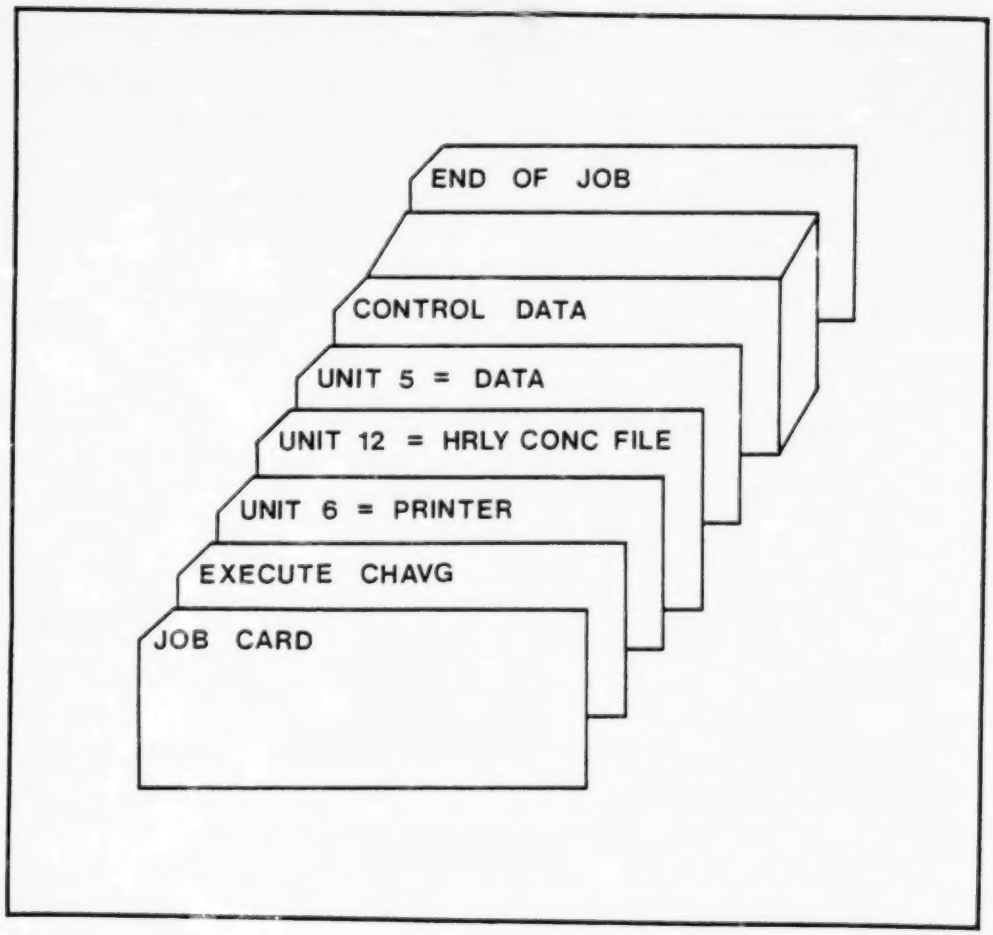

Figure 22. Sample job run-stream from CHAVG (Catalano, et al., 1982).

TABLE 2. RAMMET ERROR MESSAGES AND CORRECTIVE ACTION

MESSAGE:	ID DOES NOT MATCH IN RECORD ZZZZZ ID ON TAPE IS XXXXX ID REQUESTED IS XXXXX. *****DATA IS MISSING. PLEASE CORRECT INPUT FILE*****.
DESCRIPTION:	The surface station number in the control card does not agree with the station number in the surface meteorology file.
ACTION:	Correct the station numbers to agree with one another.
MESSAGE:	THE JULIAN DAY IN RANDOM NUMBER FILE, XXX DOES NOT AGREE WITH JULIAN DAY OF THE LOOP, XXX.
DESCRIPTION:	The Julian day input on unit 5 (random number file) does not agree with day loop subscript.
ACTION:	Correct the card in error in the random number file.
MESSAGE:	YEAR IS XX INSTEAD OF XX. IREC = ZZZZ *****DATA IS MISSING. PLEASE CORRECT INPUT FILE*****.
DESCRIPTION:	The year input on unit 5 does not match the year in the input tape on unit 8.
ACTION:	Correct year on card input to agree with year on meteorology tape input or vice versa.
MESSAGE:	MONTH DOES NOT AGREE WITH LOOP XX IREC = ZZZZ
DESCRIPTION:	Month input in the surface meteorology file does not agree with the month counter internally kept.
ACTION:	Correct the month field on the input record to agree with either the month or 1 plus the month in progress.
MESSAGE:	DAY XXX DOES NOT AGREE WITH LOOP XXX IREC = ZZZZ
DESCRIPTION:	Julian day from the surface meteorology input does not agree with day loop subscript.
ACTION:	Correct the Gregorian date input to agree with the day loop subscript.

Figure 23. Sample error messages and corrective action (Catalano, 1978).

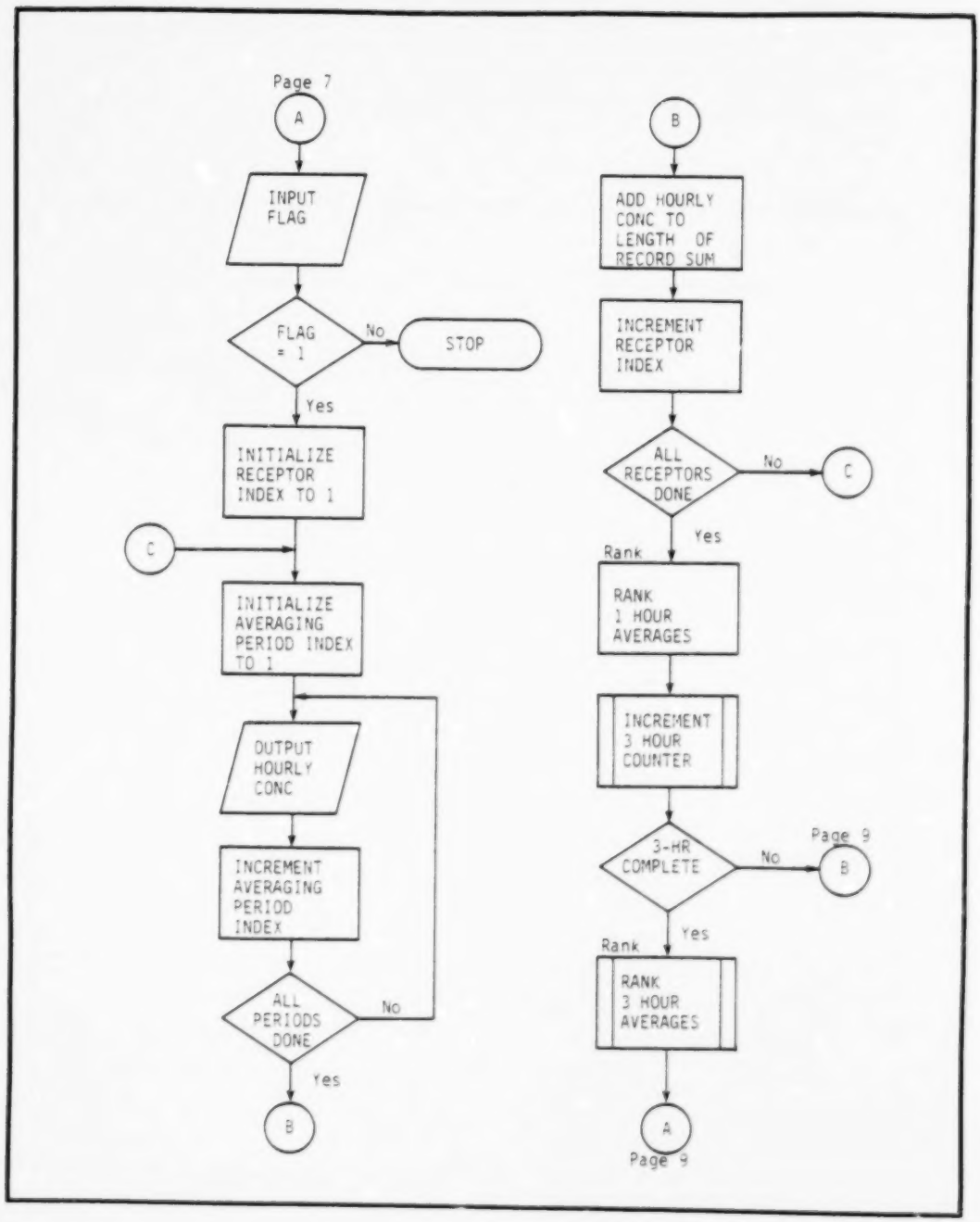

Figure 24. Sample program flow chart.

Source Code

The source code for the model should be presented if it will be of value to the user. Efforts should be made to present the source code legibly. As with the examples, reduction of computer printouts often decreases legibility of the material.

BACK MATTER

The back matter of the user's guide, consisting of references, glossary, appendices, and forms, is meant to present additional information which will be useful to the reader.

References

All material referenced in the user's guide should be listed in bibliographical form. The references should provide enough information so that the reader can locate materials noted in the text. Both the "author-year" and the "numbered" system are commonly used. An example of the "author-year" system, which is preferred, is given in Figure 25.

Glossary

Any unfamiliar terminology employed in the text should be listed and defined in a glossary. If there are fewer than ten unfamiliar terms, they are best defined within the text.

Appendices

Large amounts of related information which do not fit into any of the sections of the user's guide may be placed in appendices. In general, however, most of the necessary information will be in the body, and there will be no need for appendices.

REFERENCES

Briggs, Gary A., 1969: Plume Rise, USAEC Critical Review Series, TID-25075, National Technical Information Service, Springfield, Va. 81 pp.

Briggs, Gary A., 1971: Some recent analyses of plume rise observation, in Proceedings of the Second International Clean Air Congress, edited by H.M. Englund and W.T. Beery. Academic Press, New York. pp. 1029-1032.

Briggs, Gary A., 1972: Discussion on chimney plumes in neutral and stable surroundings. Atmos. Environ. 6: 507-510.

Briggs, Gary A., 1973: Diffusion Estimation for Small Emissions. Atmos. Turb. and Diff. Lab.,Contribution File No. (Draft) 79. Oak Ridge, Tenn. 59 pp.

Briggs, Gary A., 1975: Plume rise predictions, Chapter 3 (pp. 59-111) in Lectures on Air Pollution and Environmental Impact Analysis. Duane A. Haugen, editor, Amer. Meteorol. Soc. Boston, Mass. 296 pp.

Gifford, Franklin A., Jr., 1960: Atmospheric dispersion calculations using the generalized Gaussian plume model, Nucl. Saf. 2 (2): 56-59.

Gifford, Franklin A., and Hanna, Steven R., 1971: Urban air pollution modeling, in Proceedings of the Second International Clean Air Congress, edited by H.M. Englund and W.T. Beery. Academic Press, New York. pp 1146-1151.

Gifford, Franklin A., 1976: Turbulent diffusion-typing schemes: a review, Nucl. Saf., 17 (1): 68-86.

Holzworth, George C., 1972: Mixing Heights, Wind Speeds, and Potential for Urban Air Pollution through the Contiguous United States. Office of Air Programs Publication No. AP-101. U.S. Environmental Protection Agency, Raleigh, N.C. 118 pp.

McElroy, James L., and Pooler, Francis, 1968: St. Louis Dispersion Study. Volume II-Analysis, National Air Pollution Control Administration. Publication No. AP-53. U.S. Dept. of Health Education and Welfare, Arlington, Va. 51 pp.

Novak, Joan Hrenko, and Turner, D. Bruce, 1976: An efficient Gaussian-plume multiple-source air quality algorithm, J. Air Poll. Control Assoc., 26 (6): 570-575.

Figure 25. References from RAM User's Guide (Turner and Novak, 1978a).

SECTION 3

CODING TECHNIQUES WHICH ASSIST DOCUMENTATION

Programs of the complexity common to dispersion models must be presented in a clear and orderly style if the code is to be efficiently documented, written, debugged, maintained, and understood by others. By its very nature, FORTRAN, the language in which most dispersion models are written, lends itself all too readily to the development of programs which resemble tangled meshes of logical fragments rather than orderly representations of the logical processes on which the model is based. Because of this inherent weakness of FORTRAN and many other programming languages, certain coding techniques which reduce the possibility that the logic will be fragmented have been developed. The computer science literature of recent years abounds with information on the techniques of structured programming (Davis and Hoffman, 1978; Friedman and Koffman, 1977; and International Business Machines, 1977). These techniques are a means of limiting the programmer to a basic set of logical constructs which, when used properly, will prevent the fragmentation of the logic which is possible with "unstructured" language. In addition to these techniques, other practices related to comments, variable names, code optimization, etc. are discussed in this section. They are designed to assist the dispersion modeler and/or programmer in developing code which can be easily documented, written, debugged, maintained, and understood by others.

Experience indicates that it is best to develop a sizeable portion of the user's guide at the time the program is being developed. In this way, the order in the document will assist the programmer in writing orderly code, and the order in the code will assist with orderly documentation. Thus, one obtains both organized user's guides and organized programs.

ORGANIZATION FROM THE TOP DOWN

A dispersion model may be viewed at different levels of abstraction. The highest level of abstraction of the model is the user's guide; the lowest level is the collection of FORTRAN statements which make up the code. In principle, given the user's guide, one should be able to construct the code by increasing the level of detail, and given the code, one should be able to construct the user's guide by increasing the level of abstraction. Since both the code and the user's guide are necessary, the question becomes one of order of development.

It is clear that there is a large amount of detail starting at the level of the source code. If a modeler begins by coding the first calculation, then the second, and so on, somewhere along the way he will realize that he

forgot something earlier. He might remedy this by going back and adding code to account for the oversight. This process of realizing oversights and correcting them will continue until the model is completed. At that point, however, the code may very well be a jumble of added statements and branches. Such a program is hard to document because of the difficulty of determining its function and logic. Needless to say, such a program is also very difficult to maintain.

On the other hand, starting with the user's guide and beginning at a very abstract level, organization becomes easy--there are few details to consider. Once the technical description, data requirements, and an example problem have been written, the input, processing, and output of the code can be clearly outlined. A typical dispersion model could have the following outline:

```
Read input data
Calculate plume characteristics
(Loop over hours)
   (Loop over receptors)
      (Loop over sources)
         Calculate partial concentration
      (End loop over sources)
      Calculate concentration at receptor
   (End loop over receptors)
   Rank receptor concentrations
   Write hourly concentrations
(End loop over hours)
Write concentration summary
```

this can easily be coded as a main routine with each functionally independent item written as a subroutine. In this way the program is neatly segmented into seven discrete logical and functional units. Each of the units may then be outlined further, and additional levels of subroutines may be added as needed. Eventually, by adding one level of detail at a time, the level of the FORTRAN statements will be reached, and the model will be coded in a very organized manner--from the top down.

If the code is developed in this way, much of the work of documentation is done before the model is ever compiled. The data requirements, input format, options, features, technical description, computer aspects, and run-time environment should all be drafted before the code is completed. The outlines developed while the code is designed can be drawn and included in the flow diagram section; the sample input deck can be used as the unit test.

This method also simplifies the task of debugging. Because the program is neatly and logically divided, there are few opportunities for errors due to the logical intricacies. In general the logic will be quite simple and maintenance much easier. Because the code is logically divided into subroutines, a change to one subroutine can only affect the given procedure and a limited part of the calling routine.

BASIC LOGIC CONSTRUCTS

Every program can be clearly written with only four simple logical constructs. The instructions in a program are either executed in sequence, executed based upon a Boolean expression (IF-THEN-ELSE), repeated until some Boolean expression changes its value (DO-UNTIL), or any one of a number may be executed based upon an index (CASE). Figure 26 presents these four basic logical constructs. Proper utilization of these structures will eliminte the tangled meshes of logical fragments which can develop in a FORTRAN program.

COMMENTS

Comments in a FORTRAN program should serve two purposes: they should provide basic documentation for the program, and they should provide a narrative of the processes and equations of which the program is constructed. Good comments in a program can make the task of understanding that program much easier. Conversely, incorrect or misleading comments can make the task much more difficult.

Preliminary comments should constitute the first section of the program. Information such as program name, version, authors and their addresses, level of program support, abstract of the program, and a glossary should appear in this section. Also given should be a five digit version number consisting of two digits for the year and three digits for the Julian day on which the code was finalized. If the code is not actively supported, this should be so stated. Figure 27 provides an example of preliminary comments.

The description of the program's input and output is a particularly important part of the preliminary comments. All I/O units used should be defined, and the data format should be described. It is helpful to indicate whether the files are input or output, their size, and any special conditions related to their use (for example, if they depend upon an option). Figure 28 provides sample input/output comments.

Narrative comments should be used to describe the procedural structure of the program. There should be enough of them so that a person with a knowledge of FORTRAN can read the program and understand the logic. Examples of such comments are "BEGIN LOOP OVER HOURS," "READ CARD TYPE 12," and "IF IOPT(3) = 1, CONSIDER BUOYANCY-INDUCED DISPERSION." Each logical section of the program should also begin with a brief paragraph of comments describing it. In addition, narrative comments should be used to give references and explanations of equations used. These comments should be indented to be seen easily. Figure 29 provides an example of narrative comments.

SEQUENCE NUMBERS

Sequence numbers on the right-hand side should be consecutive in increments of ten and should contain three letters identifying the program or subroutine. Often used are three letters of the program name followed by five digits. This is highly recommended.

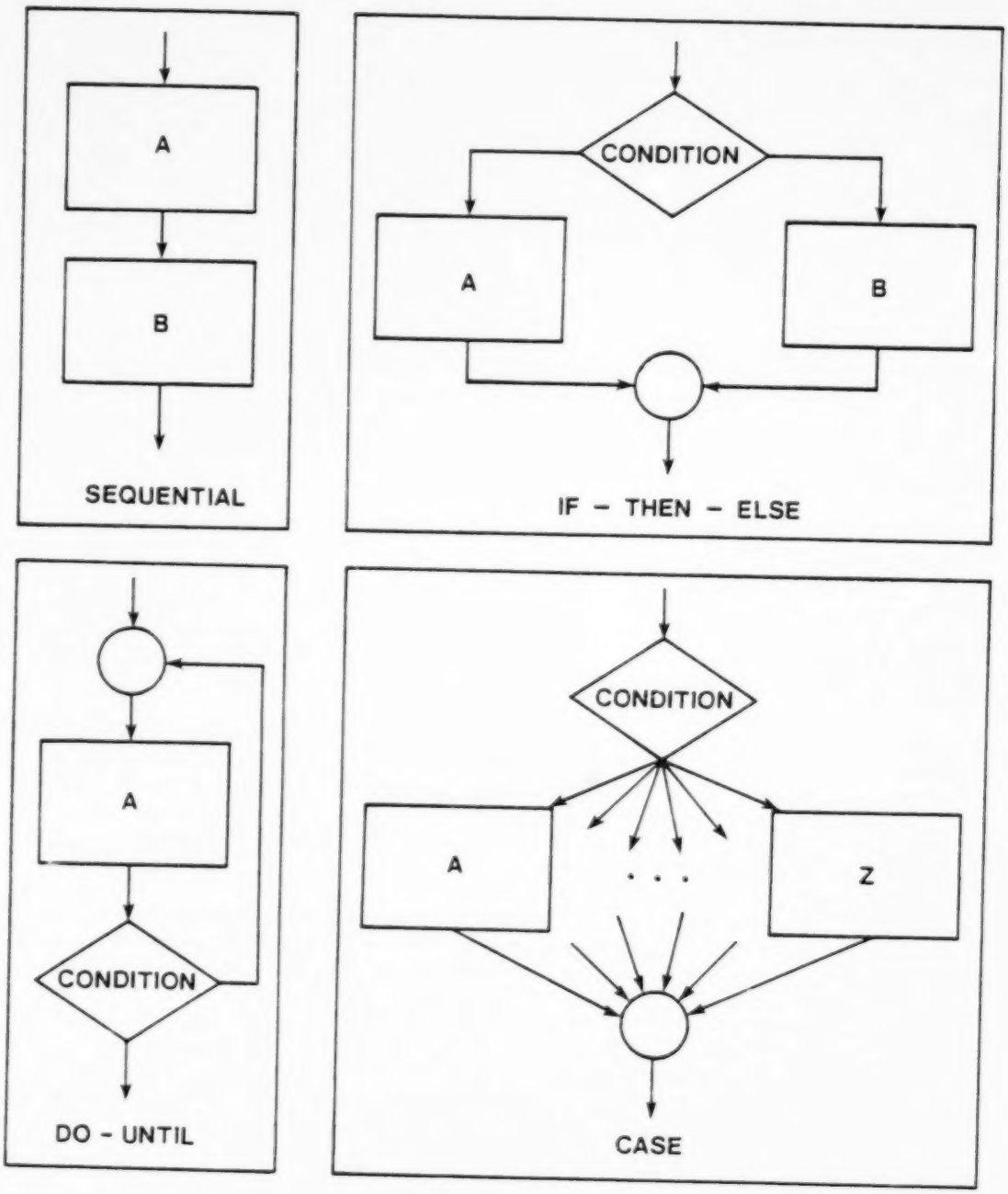

Figure 26. Basic program logic structures.

```
C     PTPLU VERSION 81036                                                    PLB00010
C     THIS IS THE BATCH VERSION OF PTPLU.                                    PLB00020
C                                                                            PLB00030
C     PTPLU ABSTRACT:                                                        PLB00040
C        PTPLU FEATURES SEVERAL IMPROVEMENTS OF THE PTMAX                    PLB00050
C        ALGORITHM. THE ANALYSIS OF CONCENTRATION HAS BEEN                   PLB00060
C        EXPANDED TO INCLUDE COMPUTATIONS BASED ON INCREASED                 PLB00070
C        WIND SPEED WITH HEIGHT FROM USER INPUT WIND PROFILE                 PLB00080
C        EXPONENTS. OTHER FEATURES INCLUDE OPTIONS FOR CALCULATION           PLB00090
C        OF GRADUAL PLUME RISE, STACK DOWNWASH, AND INITIAL                  PLB00100
C        PLUME SIZE DUE TO BUOYANCY INDUCED DISPERSION.                      PLB00110
C                                                                            PLB00120
C     PTPLU AUTHORS:                                                         PLB00130
C        THOMAS E. PIERCE AND D. BRUCE TURNER                                PLB00140
C        (ON ASSIGNMENT FROM NOAA)                                           PLB00150
C        ENVIRONMENTAL OPERATIONS BRANCH (MD - 80)                           PLB00160
C        METEOROLOGY AND ASSESSMENT DIVISION, ESRL                           PLB00170
C        ENVIRONMENTAL PROTECTION AGENCY                                     PLB00180
C                                                                            PLB00190
C     PTPLU MODIFIED BY:                                                     PLB00200
C        JOE CATALANO AND FRANK HALE                                         PLB00210
C        AEROCOMP, INC.                                                      PLB00220
C        3303 HARBOR BLVD.                                                   PLB00230
C        COSTA MESA, CA  92626                                               PLB00240
C                                                                            PLB00250
C     PTPLU SUPPORTED BY:                                                    PLB00260
C        ENVIRONMENTAL OPERATIONS BRANCH                                     PLB00270
C        MAIL DROP 80, EPA                                                   PLB00280
C        RESRCH TRI PK, NC 27711                                             PLB00290
C                                                                            PLB00300
C        PHONE: (919) 541-4564   FTS 629-4564                                PLB00310
C                                                                            PLB00320
C         PTPLU INPUT:                                                       PLB00330
C        DATA IN CARD TYPES  1,2 AND 4 MUST BE SEPARATED BY A SPACE          PLB00340
C        OR A COMMA TO BE COMPATIBLE WITH UNIVAC'S FREE FORMAT.              PLB00350
C        ADDITIONAL SOURCES CAN BE COMPUTED WITH EXTRA INPUT OF CARD         PLB00360
C        TYPES 3 AND 4. TWO BLANK DATA CARDS FOLLOW TO TERMINATE             PLB00370
C        EXECUTION.                                                          PLB00380
C                                                                            PLB00390
C     <<<<<< CARD TYPE ONE (FREE FORMAT) >>>>>>                              PLB00400
C  VARIABLE      DESCRIPTION                                                 PLB00410
C   IOPT(1)      GRADUAL RISE OPTION    0: DO NOT COMPUTE GRADUAL RISE       PLB00420
C                                       1: COMPUTE GRADUAL RISE              PLB00430
C   IOPT(2)      STACK DOWNWASH OPTION  0: DON'T COMPUTE DOWNWASH            PLB00440
C                                       1: DO COMPUTE DOWNWASH               PLB00450
C   IOPT(3)      BUOYANCY INDUCED DISPERSION                                 PLB00460
C                                       0: NONE COMPUTED                     PLB00470
C                                       1: USE PASQUILL'S TECHNIQUE          PLB00480
C   T            AMBIENT AIR TEMPERATURE (DEG, K)                            PLB00490
C   HL           MIXING HEIGHT (METERS)                                      PLB00500
```

Figure 27. Preliminary comments in PTPLU (Pierce, et al., 1982).

```
10      TABLE(2,I)=0.                                                          MPT03610
        DO 40 I=1,180                                                          MPT03620
        SUM(I)=0.                                                              MPT03630
        DO 30 J=1,5                                                            MPT03640
        CONC(I,J)=0.                                                           MPT03650
        DO 20 K=1,5                                                            MPT03660
20      HMAXA(J,I,K)=0.                                                        MPT03670
30      CONTINUE                                                               MPT03680
40      CONTINUE                                                               MPT03690
C          I/O DEVICE INITIALIZATIONS                                          MPT03700
        IN=5                                                                   MPT03710
        IO=6                                                                   MPT03720
C          UNIT 11 - DISK INPUT OF MET DATA--USED WHEN IOPT(5)=1.              MPT03730
C          UNIT 10 - DISK OUTPUT OF PARTIAL CONCENTRATIONS                     MPT03740
C           AT EACH RECEPTOR--USED WHEN IOPT(21) = 1.                          MPT03750
C          UNIT 12 TAPE/DISK OUTPUT OF HRLY CONCENTRATIONS-IF IOPT(22)=1.      MPT03760
C          UNIT 13 TAPE/DISK OUTPUT OF CONCENTRATIONS FOR AVERAGING PERIODMPT03770
C             USED IF IOPT(23) = 1.                                           MPT03780
C          UNIT 14 TAPE/DISK STORAGE FOR SUMMARY INFO, USED IF IOPT(20)=1.MPT03790
C          UNIT 15 - TAPE/DISK INPUT OF HOURLY POINT SOURCE EMISSIONS          MPT03800
C             - USED IF IOPT(6) = 1.                                           MPT03810
C                                                                             MPT03820
C          READ CARDS 1-3  (SEE DESCRIPTION, SECTION B).                      MPT03830
C                                                                             MPT03840
        READ (IN,1180) LINE1,LINE2,LINE3                                       MPT03850
        WRITE (IO,1400) LINE1,LINE2,LINE3                                      MPT03860
C                                                                             MPT03870
C          READ CARD TYPE 4  (SEE DESCRIPTION, SECTION B).                    MPT03880
C                                                                             MPT03890
        READ(IN,  *  ) IDATE(1),IDATE(2),IHSTRT,NPER,NAVG,IPOL,NSIGP,NAV5,MPT03900
       1CONONE,CELM,HAFL                                                       MPT03910
C          THE ABOVE FORMAT IS UNIVACS FREE FIELD INPUT.                      MPT03920
C          VARIABLES MUST BE SEPARATED BY COMMAS.                             MPT03930
C          THIS IS SIMILIAR TO IBM'S LIST DIRECTED IO.                        MPT03940
        IF (NSIGP.LE.25) GO TO 50                                              MPT03950
        WRITE (IO,1250) NSIGP                                                  MPT03960
        STOP                                                                   MPT03970
50      IP=IPOL-2                                                              MPT03980
        CONTWO=CONONE                                                          MPT03990
C                                                                             MPT04000
C            ********************************************                     MPT04010
C            *      SEE IMPORTANT MESSAGE                 *                  MPT04020
C            *           NUMBER 2 ABOVE!                  *                  MPT04030
C            ********************************************                     MPT04040
C                                                                             MPT04050
C           READ CARD TYPE 5   (SEE DESCRIPTION, SECTION B).                  MPT04060
C                                                                             MPT04070
        READ (IN,  *  ) (IOPT(I),I=1,24)                                      MPT04080
C            WRITE GENERAL INPUT INFORMATION                                  MPT04090
        WRITE (IO,1410) TITLE(IP),NPER,NAVG,IHSTRT,IDATE(2),IDATE(1),CONTWMPT04100
       1O,NSIGP                                                                MPT04110
        DAY1A=IDATE(2)                                                         MPT04120
        HR1=IHSTRT                                                             MPT04130
        IF (HAFL.GT.0.0) GO TO 60                                              MPT04140
```

Figure 28. Input/output comments in MPTER (Pierce and Turner, 1980).

```
C***   SUBROUTINE SPLEMT                                                PLI05680
C***   CHANGE METEOROLOGY                                               PLI05690
C                                                                       PLI05700
      SUBROUTINE SPLMET(T,HL,HANE,PL)                                   PLI05710
      DIMENSION PL(6)                                                   PLI05720
      IOUT=6                                                            PLI05730
      IN=5                                                              PLI05740
C                                                                       PLI05750
C***   DISPLAY METEOROLOGY                                              PLI05760
C                                                                       PLI05770
  100 WRITE(IOUT,900)T,HL,HANE,PL                                       PLI05780
  900 FORMAT(' 1)T:',F5.1,' 2)HL:',F6.1,' 3)HANE:',F5.1,                PLI05790
     .' 4)PL:',F3.2,5(1X,F3.2),' 5)RETURN')                             PLI05800
C                                                                       PLI05810
C***   REQUEST CHANGE                                                   PLI05820
C                                                                       PLI05830
      READ(IN,*)ICHG                                                    PLI05840
      IF (ICHG.EQ.5) RETURN                                             PLI05850
      IF ((ICHG.GT.0).AND.(ICHG.LT.5)) GO TO 120                        PLI05860
      GO TO 100                                                         PLI05870
  120 GO TO (210,220,230,240),ICHG                                      PLI05880
C                                                                       PLI05890
C***   CHANGE AMBIENT AIR TEMPERATURE                                   PLI05900
C                                                                       PLI05910
  210 READ(IN,*)T                                                       PLI05920
      CALL RCHECK(T,220.,350.,J)                                        PLI05930
      IF (J.EQ.0) GO TO 210                                             PLI05940
      GO TO 100                                                         PLI05950
C                                                                       PLI05960
C***   CHANGE MIXING HEIGHT                                             PLI05970
C                                                                       PLI05980
  220 READ(IN,*)HL                                                      PLI05990
      CALL RCHECK(HL,0.,99999.,J)                                       PLI06000
      IF (J.EQ.0) GO TO 220                                             PLI06010
      GO TO 100                                                         PLI06020
C                                                                       PLI06030
C***   CHANGE ANEMOMETER HEIGHT                                         PLI06040
C                                                                       PLI06050
  230 READ(IN,*)HANE                                                    PLI06060
      CALL RCHECK(HANE,0.,200.,J)                                       PLI06070
      IF (J.EQ.0) GO TO 230                                             PLI06080
      GO TO 100                                                         PLI06090
C                                                                       PLI06100
C***   CHANGE WIND PROFILE EXPONENTS                                    PLI06110
C                                                                       PLI06120
  240 READ(IN,*)PL                                                      PLI06130
      CALL RCHECK(PL(1),0.,2.,J)                                        PLI06140
      IF (J.EQ.0) GO TO 240                                             PLI06150
      CALL RCHECK(PL(2),0.,2.,J)                                        PLI06160
      IF (J.EQ.0) GO TO 240                                             PLI06170
      CALL RCHECK(PL(3),0.,2.,J)                                        PLI06180
      IF (J.EQ.0) GO TO 240                                             PLI06190
      CALL RCHECK(PL(4),0.,2.,J)                                        PLI06200
      IF (J.EQ.0) GO TO 240                                             PLI06210
      CALL RCHECK(PL(5),0.,2.,J)                                        PLI06220
      IF (J.EQ.0) GO TO 240                                             PLI06230
```

Figure 29. Narrative comments in PTPLU (Pierce, et al., 1982).

ORDER OF FORTRAN STATEMENTS

FORTRAN statements are of two types: non-executable and executable. It is common to organize a program with the non-executable statements first followed by the executable statements. Although the non-executable statements are generally permitted to appear anywhere in the program, locating all of them at the beginning makes understanding the program easier. The usual order of the statements is:

```
PROGRAM, FUNCTION, SUBROUTINE, or BLOCK DATA
IMPLICIT statements
Type statements such as REAL, INTEGER
DIMENSION statements
EQUIVALENCE statements
Other specifications such as EXTERNAL, SAVE, etc.
COMMON statements
DATA statements
Statement function definitions
Executable statements
END
```

GLOSSARY

A glossary defining the names in a FORTRAN program is an indispensable aid to understanding the program. Without such a glossary, each of the hundreds of names appearing in a typical FORTRAN program can be understood only by the context in which they appear. A good glossary coupled with an indexed listing of the names in a program is a very valuable maintenance tool. Each name used in the program should appear in the glossary along with its type, dimension, and definition. Some example entries follow:

NAME	TYPE	COMMON	DIMENSION	DESCRIPTION
ATM	REAL		5	AVERAGING TIMES
HMAXA	REAL	MR	5,180,5	HIGH-FIVE CONCENTRATIONS FOR EACH RECEPTOR AND EACH AVERAGING PERIOD
IN	INTEGER			CARD INPUT UNIT NUMBER
MR	COMMON			COMMON BETWEEN TPH15 AND RNK5
RNK5	SUBR			ARRANGES CONCENTRATION ARRAYS
SUM	REAL		180	LENGTH OF RECORD SUM/AVERAGE

It is helpful if the main program contains glossaries for all items in common, and the subroutines contain glossaries for all items specific to that subroutine. All subroutines should contain a glossary describing linkage parameters (dummy variables).

STANDARD FORTRAN

All FORTRAN programs should conform as much as possible to American National Standard (ANS) FORTRAN (1978). Variations from this standard which are specific to a particular FORTRAN should be clearly noted with comments. The difficulty in transporting a program to another computer is proportional to the number of non-standard features in the program. It should be noted

that the 1977 ANS FORTRAN facilitates the use of structured techniques.

OPTIMUM FORTRAN

Optimization of the code is useful in that it may reduce the cost of executing the model. However, optimization which takes much time to come upon, which decreases the readability of the code, or which depends upon a specific compiler is not very useful. In general, the best optimization technique is for the programmer to review the code and ensure there are no unnecesary or redundant calculations. Redundant calculations are often found in DO loops. Consider the following example:

```
      DO 110 I=1,100
         DO 100 J=1,100
            F(I,J)=SQRT((3+I**2)+(J**3))
100      CONTINUE
110   CONTINUE
```

For each value of I, this segment calculates 3+I**2 one hundred times, when in fact 3+I**2 should only be calculated once for each value of I. Thus 9900 extra exponentiations and 9900 extra additions are performed. The segment can be improved as follows:

```
      DO 110 I=1,100
         I2 = 3+I**2
         DO 100 J=1,100
            F(I,J)=SQRT(I2+(J**3))
100      CONTINUE
110   CONTINUE
```

The segment thus rewritten produces a more efficient set of instructions; execution costs are consequently reduced.

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